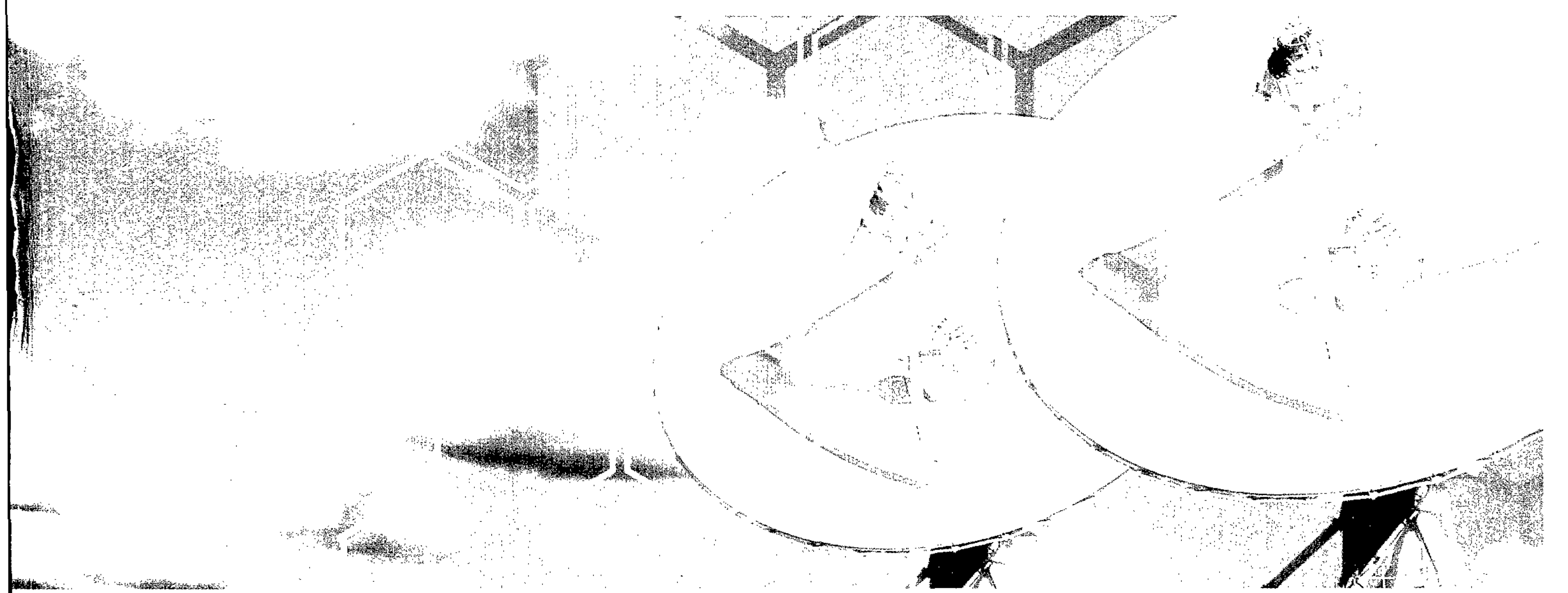
WHO Meeting on EMF Biological Effects and Standards Harmonization in Asia and Oceania

22~24 October, 2001 Shilla Hotel, **Seoul, Korea**



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ICNIRP (International Commission on Non-Ionizing Radiation Protection)
AOARD(Asian Office of Aerospace Research and Development, United States Air Force Research Laboratory)
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ETRI(Electronics and Telecommunications Research Institute)
KEES(Korea Electromagnetic Engineering Society)
RAPA(Radio Promotion Association)
IITA(Institute of Information Technology Assessment)

Homepage : www.rapa.or.kr/emf/index.htm

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14. ABSTRACT
The meeting brought together international and regional scientists for an overview of the biological and health effects and consequences of electromagnetic field exposure (EMF) devices used in the Asian and Oceania Region. Topics include: characteristics, dosimetry and measurement of EMF; mechanisms of interaction of EMF; biological effects and research needs; human studies, standards for EMF harmonization.

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PROGRAM

Monday 22 October

08:00-10:00	Registration	
10:00-10:30	Opening of Meeting	Seungtaik Yang , Minister of MIC
	Welcome	Mike Repacholi, Co-ordinator, WHO
10:30-11:00	**Coffee Break**	
11:00-11:45	WHO'S INTERNATIONAL EMF PROJECT	Mike Repacholi
11:45-12:30	REVIEW OF ANIMAL STUDIES	Bernard Veyret
12:30-14:00	**Lunch**	
14:00-14:45	EMF & CANCER: EPIDEMIOLOGIC EVIDENCE TO DATE	Leeka Kheifets
14:45-15:30	MECHANISM OF INTERACTION OF EMF	Shoogo Ueno
15:30-16:30	**POSTER PRESENTATION & COFFEE BREAK**	
16:30-17:15	REVIEW OF MOBILE PHONE EMF STUDY	Jeong-Ki PACK
17:15-18:00	CHARACTERISTICS, DOSIMETRY & MEASUREMENT OF EMF	Masao Taki
18:00-18:20	**Discussion**	
18:20	**Close**	
18:40-21:00	**Reception**	

Tuesday 23 October

09:00-09:30	REVIEW OF HEALTH EFFECTS AND GAPS IN KNOWLEDGE	Mike Repacholi
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10:00-10:30	IEEE EMF HEALTH & SAFETY STANDARDS	Patrick A. Mason
10:30-11:00	THE PRECAUTIONARY PRINCIPLE AND EMF	Leeka Kheifets
11:00-11:20	**Coffee Break**	
11:20-11:40	EMF EXPOSURE STANDARDS IN NEW ZEALAND/AUSTRALIA	Martin Gledhill
11:40-12:00	ELECTROMAGNETIC FIELD EXPOSURE STANDARD IN CHINA	Huai Chian
12:00-12:20	EMF SAFETY STANDARDS IN JAPAN	Masao Taki
12:20-12:40	EMF SAFETY STANDARDS IN MALAYSIA	Ahmed Farag
12:40-13:00	EMF STANDARDS AND RESEARCHES IN KOREA	Done-Sik Yoo
13:00-14:00	**Lunch**	
14:00-20:00	**CITY TOUR**(overseas visitors ony)	

Wednesday 24 October

09:00-09:20	CELL HYDRATION AS AN ESSENTIAL CELL PARAMETER FOR ESTIMATING THE BIOLOGICAL EFFECT OF ELECTROMAGNETIC FIELD	Sineric Ayrapetyan
09:20-09:40	ROLE OF MODULATION IN DEVELOPMENT OF EMF SOMATIC EFFECTS	Y. Grigoriev *
09:40-10:00	AN EPIDEMIOLOGICAL STUDY ON ELF-EMF AND CHILDHOOD CANCERS IN JAPAN (1999-2001)	Michinori Kabuto *
10:00-10:20	SUMMARY OF BASIC RESEARCH SUBJECTS ON BIOELECTROMAGNETIC ISSUED IN CHINA	Zhojin Cao *
10:20-10:40	DEALING WITH RADIOFREQUENCY RADIATION: THE EXPERIENCE IN THE REPUBLIC OF THE PHILIPPINES	Agnette P. Peralta and Elizabeth H. Mendoza *
10:40-11:00	**Coffee Break**	
11:00-11:20	EFFECTS OF WHOLE BODY EXPOSURE TO 50Hz ELECTROMAGNETIC FIELDS ON THE LEUKOCYTEADHESION IN MICE	A. Ushiyama and C. Ohkubo *
11:20-11:40	NATIONAL PROGRAM FOR TRAINING IN RISK PERCEPTION, RISK COMMUNICATION AND RISK MANAGEMENT AS A POLICY OF PRECAUTIONARY APPROACH	M. Israel, V. Zaryabova
11:40-12:00	DIFFERENT ASPECTS OF ELECTROMAGNETIC HYPERSENSITIVITY	A. Wojtysiak, J. Reibenweber, and E. David *
12:00-12:30	THE APPLICABILITY OF CURRENT AND PAST RF BIOLOGICAL RESEARCH TO NEW TECHNOLOGY (3G): PORTABILITY REQUIRES A MECHANISM	M. L. Swicord
12:30-12:50	EMF-RELATED ACTIVITIES IN THAILAND	Nisakorn Manatrakul
12:50-14:00	**Lunch**	
14:00-14:50	MOVIE ON THE HEALTH EFFECTS OF THE CELLULAR PHONE & BASE STATION	Femme-Michele Wagenaar
14:50-15:10	FMK SCIENCE HELP DESK	Sheila A. Johnston *
15:10-16:00	THE PURPOSE OF WHO'S EMF STANDARDS HARMONIZATION PROJECT	Mike Repacholi
16:00	**Close**	

*** This topic is also available on the poster presentation session.**

Opening Remarks

Honorable Chairman Mike Repacholi of WHO EMF Project, Chairman Lee Hyuckjae of the Organization Committee, distinguished guests, and ladies and gentlemen,

It is my great pleasure and honor to have an opportunity to speak before distinguished guests at this WHO EMF Seoul meeting where we will present research results and policies for EMF effects.

As you all know, EMF is one of the indispensable resources for us to live in the knowledge and information society of the 21st century.

EMF is used in diverse fields ranging from domestic appliances like TV and refrigerator, and communications devices like mobile phones and personal computers to medical equipment to treat cancer and broadcasting towers, all of which are designed to make our living easier and more comfortable.

However, as some raise concerns about the adverse health effects of electric fields produced by telecommunication devices of our everyday use, the biological effects of EMF has become the center of the attention in the world.

The study on the effects of the EMF exposures on human body has long been carried out, but it is not proved yet whether the EMF effect is harmful or not.

Based on the research results by experts, however, Korea and other countries like the U.S. and the U.K. have established or are preparing EMF Protection Guidelinesto help prevent possible harmful effects of electromagnatic fields.

At the same time, they are channeling their resources to scientifically prove the effects of EMF on human body.

The WHO has been studying the effects since 1996 along with 45 countries including Korea, and eight international organizations, including the ITU. The organization plans to release the result on ELF in 2002 and RF in 2004.

With a vision to build an e-Korea, a knowledge and information superpower in the 21st century, Korea has made all the necessary efforts to develop the IT industry as the key industry of our economy.

Based on one of the world's most advanced information and communication infrastructures, the IT industry of Korea has grown 20% on average each year and accounts for 29.7% of the total export last year.

In particular, the export amount for systems and handsets using CDMA wireless communications technology exceeded the two trillion won markin the first half of this year.

And as of now, the number of mobile phone users in Korea is over 28 million and the number of Internet users over 24 million.

As the number of communications device users increases day by day, the public concerns over electromanetic fields are growing at the same time.

At this critical juncture, it is very significant to hold this meeting with those responsible for the WHO EMF Project and distinguished experts from the U.S., U.K., Japan and other Asian and Oceanian countries.

I believe that this would be a good chance to resolve public concerns associated with the EMF effects by informing the public of the truth about the effects.

I sincerely hope thatthe WHO EMF Seoul Meeting would provide a venue for sharing the research results and policies of each country, thus stimulating the study on the EMF influence on human body.

In closing, I extend my sincere appreciation to all presenters and organization committee members who have worked hard to prepare this meeting successfully.

And, I hope all of you a great prosperity and development in the years ahead.

Thank you.

22 October, 2001

Minister of MIC, **Yang Seungtaik**

WHO's International EMF Project
Welcome

WHO/ICNIRP/South Korean Government meeting
EMF biological effects and standards harmonization in Asia and Oceania, 22-24 October 2001

Dr MH Repacholi
Co-ordinator, Occupational and Environmental Health
World Health Organization, Geneva, Switzerland

WHO thanks Korean Government
for hosting these important meetings

Thanks to all sponsors
and to
ICNIRP for co-hosting

Purpose

- ☞ International and regional scientists to overview biological and health effects of EMF exposure
- ☞ Discussed possible health consequences from EMF from devices used in the Asian and Oceania Region (power lines, domestic and industrial electrical appliances, mobile telephones, radars and video display terminals).

Outputs

- ☞ Proceedings of the papers presented at the meeting
- ☞ Networking of Asian and Oceania Region scientists with international scientists and WHO's project
- ☞ Summary report for web site

CONTENTS

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POSTER PRESENTATION

SLIDE PRESENTATION

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WHO'S INTERNATIONAL EMF PROJECT

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■ Abstract

With growing concern being expressed that exposure to electromagnetic fields (EMF) may cause various health effects and that everyone in the world, both in developed and developing countries, is now subjected to EMF from manmade sources, WHO established the International EMF Project in 1996 to move towards a resolution to this issue.

Briefly the International EMF Project provides: a co-ordinated international response to the concerns about possible health effects of exposure to EMF; assesses the scientific literature and make status reports on health effects; identifies gaps in knowledge needing further research to make better health risk assessments; encourages a high quality, focused research programme to fill important gaps in knowledge; incorporates research results into WHO Environmental Health Criteria monographs, in which formal health risk assessments of exposure to EMF will be made; provides information on risk perception, risk communication and risk management as they apply to EMF; provides advice and publications to national authorities on EMF issues; and facilitates the development of internationally acceptable standards for EMF exposure. This presentation provides an update of activities and outputs for the International EMF Project.

■ Introduction

The World Health Organization (WHO) takes seriously the concerns raised by reports about possible health effects from exposure to electromagnetic fields (EMF). Cancer, changes in behaviour, memory loss, Parkinson and Alzheimer's diseases, and many other diseases have been suggested as resulting from exposure to EMF. Everyone in the world is now exposed to a complex mix of EMF frequencies in the range 0-300 GHz. EMF has become one of the most pervasive environmental influences and exposure levels at many frequencies are increasing significantly as the technological revolution continues unabated and new applications using different parts of the spectrum are found. Major sources of EMF exposure include: electric power generation, distribution and use; transportation systems; telecommunications facilities and associated devices such as mobile telephones; medical, commercial and industrial equipment; radars; and radio and television broadcast antennas.

■ International EMF Project

WHO established the International EMF Project to assess health and environmental effects of exposure to static and time varying electric and magnetic fields in the frequency range 0 - 300 GHz. The Project commenced at WHO in 1996 and is scheduled for completion in about 2005. It has been designed to follow a logical progression of activities and produce a series of outputs to allow improved health risk assessments to be made and to identify any environmental impacts of EMF exposure. The ultimate objectives of the Project are to provide sound advise to national authorities on how best to manage the EMF issues, and to complete health risk assessments that will lead to the development of an international consensus on exposure guidelines. Details on the EMF Project are available on the home page at: http://www.who.ch/emf/. An overview of the complete EMF Project is shown in figure 1.

■ Scientific reviews

WHO, through its International EMF Project, has recently conducted in-depth international reviews of the scientific literature on the biological and health effects of exposure to radiofrequency (RF), intermediate frequencies as well as static and extremely low frequency (ELF) fields. These reviews were conducted with the purpose of identifying;

1. health effects that can be substantiated from the literature, and
2. biological effects that are suggestive of possible health effects, but require further research to determine if exposure to EMF at the low levels of exposure normally encountered in the living and working environment has any impact on health.

The results of these reviews have been published (Repacholi, 1998; Repacholi & Greenebaum, 1999; Litvak et al. 2001 in press). Research still needed to fill these gaps in knowledge form the WHO EMF Research Agenda that is available on the EMF Project home page or from WHO.

The proceedings of all papers from the scientific review process have been published jointly by WHO and ICNIRP, and are available from ICNIRP. Fact sheets summarizing the results of these meeting are also published by WHO.
Having completed the initial international scientific

reviews, WHO is now urging EMF funding agencies world wide to give priority to this research, if it is their intention to obtain results that will assist both WHO and the International Agency for Research on Cancer (IARC) to make better health risk assessments.

■ Health risk assessments

Both WHO and IARC have already established a timetable for assessing health effects of EMF fields. In June 2001 IARC conducted a meeting to formally identify and evaluate the evidence for carcinogenesis from exposure to static and extremely low frequency (ELF) fields. The review found that there was sufficient evidence from the childhood leukaemia studies to conclude that ELF magnetic fields are a "possible human carcinogen". IARC will publish the results of this meeting in the IARC Monograph Series later in 2001. A WHO fact sheet describing this result will be published by WHO in September 2001.

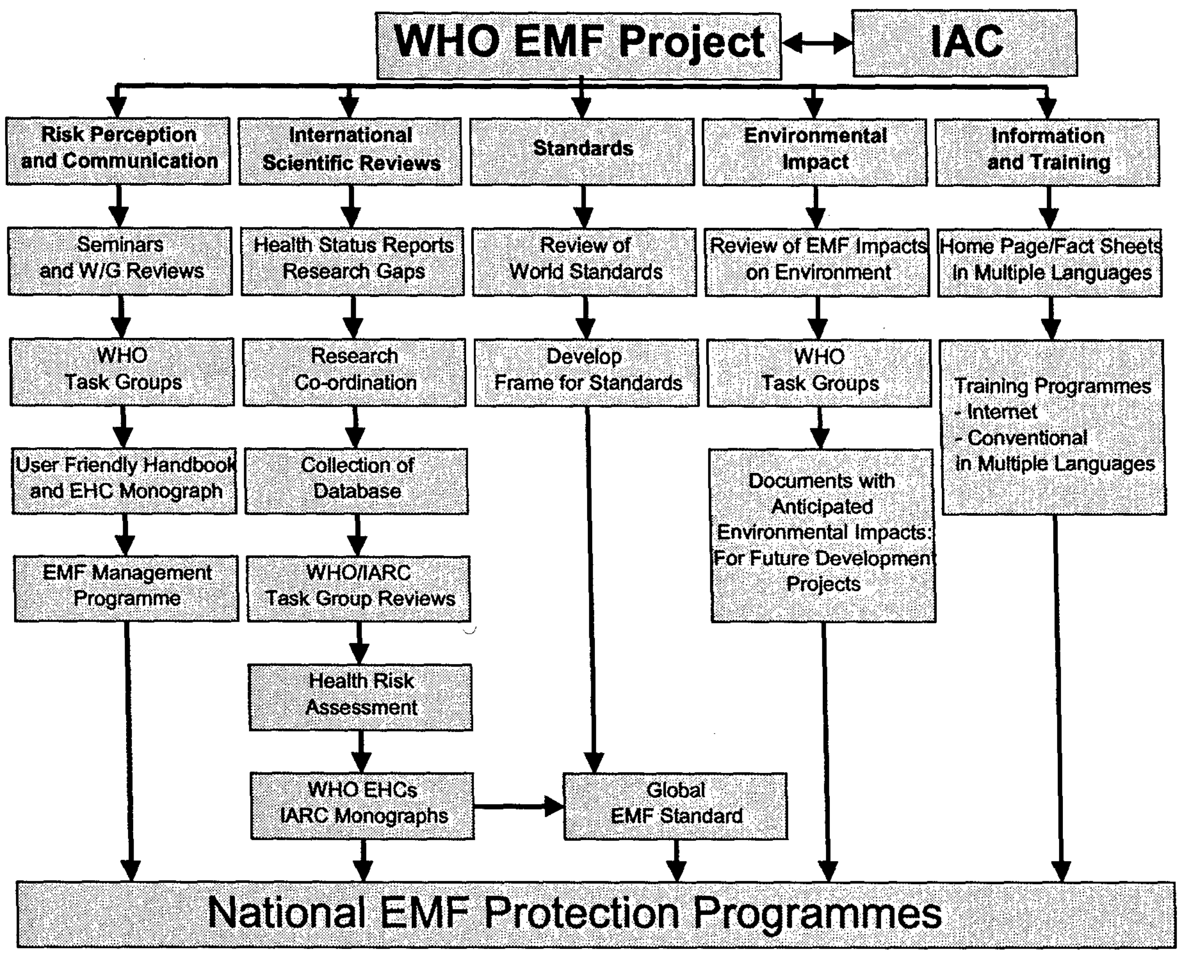

Figure 1: A schematic outline of the activities and outputs of the International EMF Project.

The International EMF Project will use the IARC conclusions on carcinogenesis and incorporate them into a full health risk assessment of exposure to static and ELF fields in 2002-3. The results and conclusions will be published in WHO's Environmental Health Criteria series. It is anticipated that sufficient results will be available for IARC to conduct a similar evaluation of evidence for carcinogenicity of RF fields in 2003-4. WHO would then complete an overall health risk assessment of exposure to RF fields in 2004-5.

■ EMF risk perception, communication and management

International seminar were held in Vienna (October 1997) and Ottawa (September 1998) to discuss application of the principles of risk perception and risk management to EMF fields. The seminars were followed by working group meetings to progress draft report on this topic. The proceedings of the Vienna seminar published by ICNIRP (1998) and the Ottawa meeting were published by WHO in 1999. From these reviews there will be publications by WHO in the form of a

monograph and a Handbook. Terms of reference for the monograph are as follows:

- Intended for use by governmental and non-governmental authorities, as well as by individuals seeking further information about this topic.

- To foster a better understanding of governmental, non-governmental, and individual views on EMF issues, how they can be better communicated, and how fruitful resolution of disagreements can be fostered.

- Provide an easily readable overview of the characteristics and underlying assumptions of peoples' perceptions of EMF risk, differences between scientific, governmental and popular views, and why these occur. Theoretical concepts of risk perception and risk communication will be presented and explained as necessary to provide context and understanding.

- Be practical and provide sufficient information for agencies and organizations to examine their current approaches to EMF and to design better and more effective information and risk management programmes. Information provided should be "user friendly" and "menu-driven" (e.g. through extensive indexing) where possible.

Its information will be useful to individuals and capable of helping them better understand the process of scientifically-based risk assessment, the approaches and assumptions involved, and their reliability. The monograph should be completed in 2002.

The Handbook will be published towards the end of 2001 and will be a user-friendly, how-to publication, with practical information for EMF program managers who need basic information on EMF risk perception, communication and management.

Both the Monograph and the Handbook publications will be available through the EMF Project at WHO.

■ Environmental Impacts

As technology has progressed, levels of EMF in our environment have increased steadily over the past 50-100 years. At specific frequencies, EMF emissions from man-made sources now exceed those from natural fields by many orders of magnitude and are detectable everywhere in the world. Significant increases in environmental EMF levels have resulted from major development projects such as high voltage transmission lines, undersea power cables, radars, telecommunication and broadcast transmitters, and transportation systems. Research has been focused to determine if EMF exposure of humans has any deleterious health consequence. By comparison, influences of these fields on plants, animals, birds and other living organisms have been less rigorously examined. Assessments of environmental impacts of EMF fields are important to:

- Ensure the preservation of balances in natural terrestrial and marine ecosystems, since these directly impact on human life.
- Preserve food supplies by ensuring there are no adverse impacts to fisheries, agricultural animals and plants.

An international seminar, organized by WHO and ICNIRP, and supported by the German Federal Office of Radiation Protection, was held in Ismaning, Germany 4-5 October 1999. It provided a summary of scientific knowledge about any consequences to the environment from man-made sources of EMF in the frequency range 0-300 GHz. Overviews of current knowledge in key areas were presented by a selected panel of recognized specialists. On the day following the seminar, working groups met (6 October 1999) to prepare conclusions and recommendations. The results of the working group meetings has been used to prepare a scientific paper for publication in a scientific journal. This has now been completed and awaits publication. The proceedings of all presentations have been published and are available from ICNIRP. A WHO fact sheet of the seminar results in lay language has been prepared and will be available before the end of 2001.

It is not anticipated that further meetings will be organized on this topic. The main purpose of this activity under the EMF Project is to provide information that specifically addresses environmental impacts of EMF fields. A comprehensive summary report on this topic will have at least two benefits. It will:

- be useful for both governmental and non-governmental institutions when conducting environmental impact assessments, and

- address any public concerns that EMF could be adversely affecting our environment.

■ Further Reading

1. Foster K R, Osepchuk J M and Repacholi M H, Environmental impacts of electromagnetic fields, Submitted to Environmental Health Perspectives September 2001.

2. Litvak E, Foster K R and Repacholi M H, Health Consequences of Exposure to electromagnetic fields in the frequency range 300 Hz to 10 MHz, Bioelectromagnetics, in press.

3. Repacholi M H, Low-level exposure to radiofrequency electromagnetic fields: Health effects and research needs, Bioelectromagnetics 19: 1-19, 1998.

4. Repacholi M H and Greenebaum B, Interaction of static and extremely low frequency electric and magnetic fields with living systems: Health effects and research needs, Bioelectromagnetics 20: 133-160, 1999.

■ Fact Sheets

The following WHO Fact Sheets concerning EMF have been published or are being drafted:

- Electromagnetic Fields and Public Health: The International EMF Project. WHO Fact Sheet #181 Oct. 1997, reviewed May 1998.
- Electromagnetic Fields and Public Health: Physical Properties and Effects on Biological Systems. WHO Fact Sheet #182 Oct. 1997, reviewed May 1998.
- Electromagnetic Fields and Public Health: Health Effects of Radiofrequency Fields. WHO Fact Sheet #183 Oct. 1997, reviewed May 1998.
- Electromagnetic Fields and Public Health: Public Perception of EMF Risks. WHO Fact Sheet #184 Oct. 1997, reviewed May 1998
- Electromagnetic Fields and Public Health: Mobile Telephones and their Base Stations. WHO Fact Sheet #193 (Revised June 2000).
- Video Display Units (VDUs) and Human Health. WHO Fact Sheet #201 July 1998
- Electromagnetic Fields and Public Health: Extremely Low Frequency (ELF). WHO Fact Sheet #205 November 1998.
- Electromagnetic Fields and Public Health: Radars and Human Health. WHO Fact Sheet #226 June 1999.
- Electromagnetic Fields and Public Health: WHO Backgrounder on Cautionary Policies. March 2000
- Electromagnetic Fields and Public Health: Are Extremely Low Frequency Fields Carcinogenic? September 2001
- Electromagnetic Fields and Public Health: EMF Hypersensitivity. WHO Fact Sheet (in preparation)
- Electromagnetic Fields and Public Health: Guidance on protection of the public. WHO Fact Sheet (in preparation)
- Electromagnetic Fields and Public Health: EMF Intermediate Frequencies and Health. WHO Fact Sheet (in preparation)
- Electromagnetic Fields and Public Health: Environmental Impacts of EMF. WHO Fact Sheet (in preparation)

■ Press Releases

The following press releases have been published by WHO on the Project:

X WHO Launches New International Project to Assess Health Effects of Electric and Magnetic Fields. Press release WHO/42, 4 June 1996.

X Electromagnetic fields: Experts Met in Vienna to Assess Public Perceptions of Risks. Press release WHO/75, 23 October, 1997.

X Health Effects of Electromagnetic Fields: WHO Recommends Research Priorities. Press release WHO/95, 19 December 1997.

X Scientists Meet in Moscow to Discuss Adverse Effects of Electromagnetic Fields. Press release WHO/38, 20 May 1998.

X WHO launches an initiative to harmonize EMF standards worldwide. Press release WHO/88, 17 November 1998.

X More information necessary to establish health effects of mobile phones. Press release WHO/45, 28 June 2000.

All press releases are available in English and French, and some are available in other languages, particularly the language of the city in which the release was issued. Further details can be obtained from the Programme Manager, Health Communications and Public Relations, WHO, Geneva, Tel: +41 22 791 2532, Fax: +41 22 791 4858. All WHO press releases can be obtained on the Internet on the WHO HOME PAGE http://www.who.int/.

REVIEW OF ANIMAL STUDIES

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■ Abstract

In the last twenty years, hundreds of experiments have been carried out on animals to assess cancer-related risks of exposure to extremely-low-frequency (ELF) and radiofrequency (RF) electromagnetic fields. Most of the work has been performed at frequencies related to the generation of electricity at 50/60Hz and mobile telephony at around 1 GHz.
Results obtained on cancer-related models are described in this brief review in terms of the risk evaluation that is necessary for the establishment of exposure guidelines and standards.
Overall, it remains true that there are no known well-documented effects leading to health risks for weak induced currents at ELF and "non-thermal" RF fields levels.

■ Introduction

There has been considerable interest and controversial debate in recent years concerning the bioeffects of electromagnetic fields (EMF). This is due to some still-unanswered questions about the effect on health of increasing levels of exposure of the population to EMF.
However, the number of experiments, articles, reviews, and databases has risen significantly. The quality of the research has improved vastly and the knowledge is now based on a wide body of data so that ICNIRP[1], IARC[2] and WHO are or will soon be able to evaluate the carcinogenicity and health risks of EMF.

This review is concerned mainly with animal models of cancer. It is divided in two parts related to the ELF and RF frequency ranges. It is intended to be complimentary to the talk to be given at the Seoul WHO meeting in terms of content and mode of presentation.
Laboratory studies on animals play an essential role in evaluating the integrated response of various systems of the body, particularly the nervous, endocrine and immune systems. These systems are largely responsible for homeostasis which maintains the internal environment. When challenged by external stimuli, the interdependent response of these systems cannot be fully defined through *in-vitro* experiments. However, phenomena seen in experimental animals do not necessarily imply a health risk for humans. In particular, an effect found in only one animal species may be specific to that type of animal and not relevant to humans.
Animal studies provide the opportunity to test whether lifetime exposure to well-characterised RF causes cancer, something that is impossible to do using human volunteers. Research on animals can also demonstrate influences of RF exposure on susceptibility to cancer promotion and progression.

■ Extremely-low-frequency fields

A major research effort was launched world-wide to determine the possible bioeffects of magnetic and electric fields at extremely low frequencies ($f < 300$ Hz, mainly 50/60 Hz corresponding to electricity generation and distribution). Following years of scattered projects, this research activity has become better co-ordinated on the international level, largely thanks to the EMF programme of WHO.
The most recent and comprehensive review on ELF bioeffects is that of the RAPID[3] programme published in 1998. In 2002, IARC is going to published a monograph on the carcinogenicity of ELF fields[4]. However the conclusions of that monograph are already available.[5]

Exposure systems

In the last twenty years, a great number of experiments have been performed in laboratories world-wide to assess the biological effects of ELF magnetic and electric fields. This has led to the design and building of several types of exposure systems for *in vivo* work. The goal was to expose the animals to well-characterised fields under well-defined environmental factors.

In view of the mechanisms of interaction of fields with biological organisms (mainly induced currents), the effects of the magnetic field, which penetrates the body, have been the main focus of the research projects, with fields strength usually at or below 100 μT.
In contrast, electric fields do no penetrate the organism because of its conductivity, but strong electric fields induce polarisation of the cell membrane leading to specific effects such as electroporation, which are studied in specific exposure systems. This is also true for direct stimulation of nerves and other excitable cells using electrodes.

There has been many improvements in the design of exposure systems in recent years and it can be stated that most of the key exposure parameters described below are well-characterised and controlled. However, the standardisation of the set-ups is only achieved within some of the multi-centre research programmes.
Large-scale studies on long-term effects of ELF magnetic fields on animals have been published in recent years. Large facilities have thus been built and run for exposure of hundreds of rodents over their lifetime[6, 7] (reviewed by Stuchly et al.[8]). Great care is being taken for controlling all environmental factors.

Genotoxicity

Effects have been found in different organisms and in particular rodents. The work performed by Lai and Singh is worth mentioning[9]. These investigators used the "comet assay" to detect DNA damage in brain cells from ELF-exposed rats. Increases in DNA double- and single strand breaks were detected after *in vivo* exposure to a 60 Hz magnetic field at 0.1-0.5 mT. These authors also indicated that the magnetic-field-induced DNA strand breaks were caused by free radicals since a treatment of the animals with free radical scavengers blocked the effects. In a subsequent investigation[10], they also found that the magnetic-field apparently induces DNA-protein and DNA-DNA cross-links in a manner similar to the chemical mitomycin C. These investigations certainly need confirmation and further investigation. There have been a number of criticisms (also on similar research on RF fields) that merit further attention.

Carcinogenesis

The controversial issues deduced from epidemiological investigations have spawned many laboratory experiments to determine whether EMF can initiate, promote or co-promote cancer in animal models.
There is no evidence that ELF magnetic fields cause tumours ("initiation"), with the possible exception of lymphomas arising after exposing rats at high-strength fields for three generations [11] but there are some inconsistent indications that EMF exposure might in some circumstances suppress or enhance tumour development/ growth.
Overall, no convincing experimental evidence has been found to support the hypothesis that exposure to ELF magnetic fields increases the risk of cancer. This conclusion is well supported by the results of a number recent large scale studies of animal carcinogenesis [12] including those using transgenic animals[13], which have generally been more carefully conducted than some of the earlier studies reporting either positive or negative effects.

Rodents, particularly mice, have been used extensively in studies of adult leukaemogenesis; in spite of the absence of a good animal model of the most common form of childhood leukaemia, i.e., acute lymphoblastic leukaemia. Most studies report a lack of effect of ELF magnetic fields on leukaemia or lymphoma in rodents. These include several recent, large-scale studies of spontaneous tumour incidence in normal and transgenic mice [14], and of radiation-induced lymphoma and leukaemia in mice. Further studies found no effect on the progression of transplanted leukaemia cells in mice or rats.

Rat mammary carcinomas represent a standard laboratory animal model in the study of human breast cancer. Three recent large-scale studies of rats showed that lifetime magnetic-field exposure had no effect on the incidence of spontaneous mammary tumours. The evidence concerning EMF effects on chemically-induced mammary tumours is more equivocal. Two studies suggested that exposure to ELF EMF increase the incidence or growth of chemically-induced mammary tumours in female rats. [15] However, the work of one laboratory was inadequately described and there was considerable inter-experimental variability in the results from the other laboratory. Two more recent studies have not been able to corroborate these findings. [16] Further experimental investigation may be warranted to resolve this uncertainty.

Whilst there is no good animal model of spontaneous brain tumour, a recent, large scale study reported a lack of effect of exposure to power frequency magnetic fields on chemically-induced nervous-system tumours in female rats[17]. In addition, the low incidence of brain cancers in three recent large-scale rat studies was not elevated by magnetic field exposure.

Studies of pre-neoplastic liver lesions and chemically-induced skin tumours have been almost uniformly negative. In addition, there is no convincing evidence of increased malignant conversion. In particular, in three recent large-scale studies of ELF magnetic-field effects on spontaneous tumour incidence in rodents, the overall proportion of malignant tumours tended to be evenly distributed between exposed and control animals and there was no evidence of a significant trend in dose-response relationship.[11]

Reproduction and development

Studies have been carried out of the reproductive and developmental effects of exposure to ELF electric and magnetic field effects using chick and mammalian species. With regard to the studies of EMF effects during the first 2-3 days of development, the data are inconclusive. Positive effects have been reported but attempts at replication have mostly been unsuccessful; in addition, a number of studies found no effect.
Studies using mammalian species are more relevant to possible effects on humans and overall, the data do not support the hypothesis that ELF EMF exposures result in reproductive toxicity. Most studies of the effects of exposure to power frequency electric fields on the development of rodents and miniature swine were negative. Similarly, exposure had little effect on rodent reproduction and development, although several studies noted an increase in the incidence of minor skeletal anomalies or variants.

Endocrine system

Most animal studies of endocrine function concern the pineal gland and melatonin, because of concerns related to cancer. Fewer studies have been carried out of ELF electromagnetic field effects on the pituitary hormones or those of other endocrine glands.
Some, but not all, studies of power frequency EMF effects on rat pineal and serum melatonin levels report that exposure to power frequency electric or magnetic fields resulted in suppression. The evidence from a series of more recent studies by another group reporting that circularly polarised magnetic fields suppress night-

time melatonin levels was sometimes weakened by inappropriate comparisons between exposed animals and historical controls[18]. The data from other experiments was equivocal but mostly negative. The evidence for an effect of exposure to ELF EMF on melatonin levels and melatonin-dependent reproductive status in seasonally breeding animals, Djungarian hamsters and Suffolk sheep, is mostly negative. No convincing effect on melatonin levels has been seen in a study of non-human primates chronically exposed to ELF EMF.

With the possible exception of transient of minute duration, stress following the onset of ELF electric field exposure at levels significantly above perception thresholds, no consistent effects have been seen in the stress-related hormones of the pituitary-adrenal axis in a variety of mammalian species.
Similarly, mostly negative or inconsistent effects have been seen in growth hormone levels, levels of hormones involved in controlling metabolic activity or associated with the control of reproduction and sexual development. Few studies have been carried out.

Immune system

There is little consistent evidence of any inhibitory effect of ELF EMF exposure on various aspects of immune system functions including those relevant to cancer. These included *in vivo* assays of T-lymphocyte mediated immune responsiveness to infection and antigen stimulation and, following *in vivo* exposure, *in vitro* assays of lymphocyte proliferation, of natural killer cell activity, macrophage activity, B-lymphocyte (antibody) cell activity and differential white blood cell counts.
Consistently reduced natural killer cell activity was seen in female mice exposed to magnetic fields but this effect was not seen in male mice nor in male or female rats[19].
In addition, EMF-induced changes in tumour incidence could not be correlated with any change in immune function.

Nervous system

Small effects have been reported on peripheral nerve function and neuromuscular function following the chronic exposure of rats to intense power frequency electric fields in well in excess of perception thresholds.
Intense, pulsed magnetic fields can induce eddy currents sufficient to stimulate nerve tissue directly.
Several papers indicate that exposure to ELF electric and/or magnetic fields can change EEG characteristics or evoked potential activity. None suggest that the effects are hazardous.[3]
A few studies have shown effects of ELF electric or magnetic field exposure on neurotransmitter levels, however, the results are mixed and the effects noted relatively small.[3] Several studies suggest possible EMF effects on the opioid and cholinergic systems. These effects should be further investigated.

Conclusion on ELF

Most reviews indicate that ELF magnetic do not produce reproducible effects on animals. However, there is still some uncertainty about DMBA models.

Further work is also needed to test a recent hypothesis which is related to the possible effects of contact currents experienced in residential environments: these currents may affect hematopoiesis and be thus related to childhood leukaemia, for which there is so far no accepted mechanism.[20]

■ Radiofrequency fields

The rapid development of mobile telephony in the last ten years has led to a large research effort in the RF range, aimed at assessing the risks related to both mobile telephones and base stations. This followed the allegations in the courts and media that mobile telephones are a cause of cancer and the public objections to the siting of TV, radio and mobile telephony antenna because of a fear of cancer.
Animal testing has contributing significantly to this research: at the present time, there are 95 of such studies, completed or on-going, listed in the WHO EMF database. Several reviews[21, 22] and institutional reports[23] have summarised the main findings

Exposure systems

Several new exposure systems have been built and validated in the recent years for head-only[24], head-mainly or whole-body exposure. The quality of the systems has improved vastly and nowdays the exposure is well-characterised and uniform.[25]

Genotoxic effects

The energy of RF photons is too weak to break bonds and thus cannot affect DNA directly. However, there have been investigations of potential epigenetic effects (indirect) at low-level.

Micronuclei: No effect was seen on blood cells in mice exposed at 2.45-GHz for 18 months at a whole-body SAR of 1 W/kg[26]. Few other such studies have been performed *in vivo*.

Chromosomal aberration: Most experiments on whole animals have shown no increase in chromosomal aberration after exposure, even at high intensities corresponding to a rise in body temperature.

DNA damage: An increase in the number of DNA breaks was reported in the brain cells of rats exposed for two hours to pulsed or continuous-wave 2.45-GHz microwaves using the "comet" assay.[27] However, several replications studies have since failed.[28]

Mutation: A large number of studies on animals have consistently failed to demonstrate mutation of somatic cells after exposure to RF microwaves even at high levels.

Cancer

Spontaneous tumour incidence: There were no effects observed in several rodent studies in normal animals but possible effects in transgenic mice as reported by the Repacholi group using transgenic mice prone to develop lymphomas[29]. Replication of this study and extension with more complete follow-up and improved dosimetry is currently under way in Australia and Italy[30]. Another In case of replication, one will need to further assess the relevance of these findings for human health. Other authors have reported a lack of effect of RF exposure on cancer incidence in mice prone to mammary tumours.[31, 32]

Promotion studies: The many co-promotion studies that have been performed using chemically-induced tumours have been consistently negative.[33], [34] There are several more such studies under way.

Progression of injected tumours: The few studies on injected tumours have been negative.

Melatonin: There are so far too few studies on melatonin levels in animals to draw ant firm conclusions. However, most of these studies were negative.

Conclusions on cancer: Some caution is required before dismissing effects on cancer completely as positive results were found in a few studies.

Acute effects on the nervous system

Gene expression
Consistent changes have been seen only with heating[35] but studies with transgenic worms suggest otherwise.[36] Further work on HSP expression is claerly needed as evidenced also in recent *in vitro* results

Blood-brain barrier (BBB) permeability
results of studies on the permeability of the BBB have mainly negative[37] but some positive effects have been reported [38] and further work is on-going in several laboratories.

Conclusions
Regarding data obtained on cancer in animal models using mobile telephone signals, there is very limited evidence of low-level effects overall. Further work is on-going that should clarify the remaining controversies.

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EMF & CANCER: EPIDEMIOLOGIC EVIDENCE TO DATE

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■ Abstract

The results of many years of epidemiologic studies concentrating on the possible health risks (particularly cancer risks) associated with exposure to electric and magnetic fields (EMF) have been equivocal. While some studies suggest that EMF could pose a health risk, the risk estimates are low, and their confidence intervals often include no effect. However, if real, even a small risk of a prevalent exposure could have major public health implications. In June 2001, an expert scientific working group of IARC reviewed studies related to the carcinogenicity of static and ELF electric and magnetic fields. Using the standard IARC classification that weighs human, animal and laboratory evidence, ELF magnetic fields were classified as possibly carcinogenic to humans based on epidemiological studies of childhood leukaemia. Evidence for all other cancers in children and adults, as well as other types of exposures (i.e. static fields and ELF electric fields) was considered not classifiable either due to insufficient or inconsistent scientific information.

Although there have been more than 200 epidemiologic studies in this area, many early studies of EMF were too limited in design and scope to do more than generate hypotheses. The number of epidemiologic studies with the methodologic wherewithal to test hypotheses is growing. Among the improvements in this new generation of studies are: *a priori* specification of hypotheses-- to better distinguish between chance occurrence and real association; examination of specific cancers, which should allow for the identification of agents specific to the etiology of a particular cancer; larger numbers of subjects to improve the precision of risk estimates; improved exposure assessment to reduce misclassification of exposure; and evaluation of a variety of potential confounders to minimize the possibility of a spurious association.

Unfortunately, the improvements in study quality have not led to a concomitant improvement in the clarity of our picture of the relationship between EMF and cancer risk. The discussion will include comments on what we have learned and why studying EMF exposure poses unique and substantial difficulties.

■ Introduction

Electricity use has grown throughout the industrialized world since the first public power station began operation in London on 12 January 1882. Electricity is generated and usually transmitted as alternating current (ac) in North America at 60 or 60 Hertz (Hz) cycles per second. In the past, exposures to ambient EMF have been thought to be without biologic effects. The first suggestion that exposures might be detrimental to one's health arose from Soviet Union studies in the early 1960's (5). Since 1979 when epidemiological studies first raised a concern about exposures to power line frequency magnetic fields and childhood leukaemia, a large number of studies have been conducted to determine if measured ELF exposure can influence cancer development, especially in children.

Concern also continues about exposure to radiofrequency (RF) fields from sources used for mobile telecommunications, radars, radio and television broadcast, medical and industrial applications. Much of this concern arises because new technologies are introduced without provision of public information about their nature or discussion of the debate within the scientific community about possible health consequences. In the meantime, mobile phone use has increased dramatically with falling costs. Industry sources suggest that there will be over one billion users worldwide by 2005, far exceeding telephone use via fixed-lines.

Of particular concern to WHO is the fact that, if any adverse health effect is established from mobile phone use or use of electricity, it will be a global concern because developing countries are establishing this technology in preference to the more-expensive fixed line systems and the use of electricity is ubiquitous. Thus even a small impact on health could have a major public health consequence.

The health effects that have received the most attention are cancer, reproductive effects and neurobehavioral effects. The evidence linking cancer to EMF exposure is discussed below

■ Long-term health effects of ELF

ELF fields are known to interact with tissues by inducing electric fields and currents in them. This is the only established mechanism of action of these fields. However, the electric currents induced by ELF fields commonly found in our environment are normally much lower than the strongest electric currents naturally occurring in the body such as those that control the beating of the heart.

There is no convincing evidence that exposure to ELF fields below currently accepted international exposure limits causes direct damage to biological molecules, including DNA. Since it seems unlikely that ELF fields could initiate cancer, a large number of investigations have been conducted to determine if ELF exposure can influence cancer promotion or co-promotion. Results

from animal studies used in the health risk assessments have been mostly negative.

However, two recent pooled analyses of epidemiological studies provide insight into the epidemiological evidence on childhood leukemia. These studies suggest that, in a population exposed to average magnetic fields in excess of 0.3 to 0.4 µT, twice as many children might develop leukaemia compared to a population with lower exposures. In spite of the large number data base, some uncertainty remains as to whether magnetic field exposure or some other factor(s) might have accounted for the increased leukaemia incidence.

Childhood leukaemia is a rare disease. Approximately, 4 out of 100,000 children between the age of 0 to 14 are diagnosed with childhood leukaemia every year. In addition, average magnetic field exposures above 0.3 or 0.4 µT in residences are rare.

Other studies of residential exposure from EMF are largely negative thus far, for a detailed review of residential studies, see Kheifets, 1997.

Over 80 occupational studies have examined magnetic fields as a potential risk factor for a variety of cancers. A few of these studies also considered electric fields as a risk factor, and one investigated the combination of electric and magnetic fields appearing together. These studies have varied widely in the design, types of study subjects, methods of exposure assessment, outcomes considered and quality.

Of the many cancers and exposures examined, a consistent small increase in the risk of leukemia and brain tumors in electrical workers is noted. Because of the large number of occupational studies of EMF and leukemia and brain cancers, specific study references which have been included in meta-analyses are omitted below. Please refer to Kheifets et al., 1995 and 1997 for a more detailed review of the literature.

The risks of leukemia associated with exposure to EMF are generally low; pooled analyses suggest an excess of all leukemias with a risk estimate of 1.18 (95 percent confidence interval (CI) 1.12-1.24) (11), with slightly higher risks for the various leukemia subtypes. Although most studies reported a small elevation in risk, the apparent lack of a clear pattern of exposure to EMF substantially detracts from the hypothesis that magnetic fields in the work environment are responsible for it. These findings were not sensitive to assumptions, influence of individual studies, weighting schemes, or modeling. Some evidence of publication bias was noted (12).

Similarly, there is a small but significant increase in brain cancer risk associated with estimates of potential workplace magnetic field exposure RR = 1.21 (CI 1.11-1.33) (13). While most studies reported a small elevation in risk, there was considerable heterogeneity in the results. The findings of this meta-analysis were not affected by inclusion of unpublished data, influence of individual studies, weighting schemes, or model specification.

Despite the large number of studies published, several endpoints have not been rigorously examined in a sufficient number of studies. As the methodology of studies improved, the estimates of risk have become lower, making it unlikely that a large risk is being missed. Nevertheless, a sufficient uncertainty remains as to the potential of EMF involvement in cancer etiology. Even a small risk associated with a ubiquitous exposure could have important public health consequences.

In June 2001, an expert scientific working group of IARC reviewed studies related to the carcinogenicity of static and ELF electric and magnetic fields. Using the standard IARC classification that weighs human, animal and laboratory evidence, ELF magnetic fields were classified as possibly carcinogenic to humans based on epidemiological studies of childhood leukaemia. Evidence for all other cancers in children and adults, as well as other types of exposures (i.e. static fields and ELF electric fields) was considered not classifiable either due to insufficient or inconsistent scientific information.

"Possibly carcinogenic to humans " is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

The IARC review addresses the issue of whether it is feasible that ELF-EMF pose a cancer risk. The next step in the process is to estimate the likelihood of cancers in the general population from the usual exposures and to evaluate evidence for other (non-cancer) diseases. This part of the risk assessment should be finished in the next 18 months.

Recent increased use of wireless communications has brought forth new concerns about biological effects of radiofrequency (RF) radiation. While it is well established that at higher power levels RF energy can produce deleterious effects, today's wireless communication systems employ a low power modulated form of RF radiation, the effects of which are still uncertain (Lin JC. Health effects of radiofrequency radiation from wireless communication technology, Advances in Electromagnetic Fields in Living Systems, vol. 2, 1997:129-164.)

In their review of cancer studies, the IEGMP (2000) concluded that: Some individual experimental studies have suggested that RF radiation can initiate tumour formation, enhance the effects of known carcinogens or promote the growth of transplanted tumours. However, in some of these the intensity was high enough to produce thermal effects. The balance of evidence, from both in vitro and in vivo experiments, indicates that neither acute nor chronic exposure to RF fields increases mutation or chromosomal aberration frequencies when

temperatures are maintained within physiological limits (UNEP/WHO/IRPA, 1993). This suggests that RF exposure is unlikely to act as a tumour initiator. Further, a variety of cancer studies using animals have sought evidence of an effect of RF exposure on spontaneous or natural cancer rates, the enhancement of the effects of known carcinogens or effects on the growth of implanted tumours. However, they have provided equivocal evidence for an effect on tumour incidence (ICNIRP, 1998; Repacholi, 1998; Moulder et al, 1999; Royal Society of Canada, 1999).

By far the greatest public concern has been that exposure to low-level RF fields may cause cancer. Of the epidemiological studies addressing possible links between RF exposure and excess risk of cancer, some positive findings were reported for leukaemia and brain tumours. Overall, the results are inconclusive and do not support the hypothesis that exposure to RF fields causes or influences cancer.

Review groups evaluating possible links between RF exposure and excess risk of cancer have concluded that there is no consistent evidence of a carcinogenic hazard. In some studies there are significant difficulties in assessing disease incidence with respect to RF exposure and with potential confounding factors such as ELF and chemical exposure. Overall the epidemiological studies suffer from inadequate assessment of exposure and insufficient latency, since mobile phones have not been in use for long enough to allow comprehensive epidemiological assessment of their impact on health. In addition, rapidly changing technology makes epidemiologic studies in this area particularly difficult.

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Mechanisms of Interaction of EMF

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■ Introduction

This paper reviews the mechanisms responsible for the biological effects associated with electromagnetic fields (EMF). The EMF effects are classified into four categories; the effects of static magnetic fields, extremely low frequency (ELF) magnetic fields, pulsed magnetic fields, and radio frequency (rf) electromagnetic fields. The effects of EMF used in mobile telephones, residential environments, and medical applications such as MRI and transcranial magnetic stimulation of human subjects are discussed.
Time-varying magnetic fields produce eddy currents that stimulate excitable tissues, such as nerve and muscle, at low frequencies, and generate heat in tissues at high frequencies. Magnetic brain stimulation can be realized by this stimulating effect.
The possible biological effects of rf fields are discussed in terms of a specific absorption rate (SAR) [W/kg]. The high energy of rf field exposure generates high SAR values, which cause thermal effects in biological tissues. However, the so-called non-thermal effects, or, the biological effects of rf fields at low energy levels have not been clarified yet. The biological effects of ELF and transient magnetic fields at residential and environmental levels are also poorly understood. There are many possible models and hypotheses to explain the ELF and rf field effects at low SAR levels. Further in vitro and in vivo studies are necessary to clarify the mechanisms associated with low-level rf effects, amplitude-modulated or frequency-modulated rf effects, and low level ELF effects.
The biological effects of static magnetic fields are poorly understood. Recognition of the role of diamagnetic, paramagnetic and ferromagnetic materials in the body may help in unraveling the underlying mechanisms.
Table 1 shows some of the mechanisms responsible for the biological effects of magnetic and electromagnetic fields.

Table 1 Mechanisms of biological effects of electromagnetic fields

i) time-varying magnetic field		
eddy currents	$J = -\sigma \dfrac{\partial B}{\partial t}$	nerve stimulation
heat	$SAR = \sigma \dfrac{E^2}{\rho}$	thermal effects
ii) homogeneous magnetic field		
magnetic torque	$T = -\dfrac{1}{2\mu_0} B^2 \Delta\chi \sin 2\theta$	magnetic orientation of biological cells
iii) inhomogeneous magnetic field		
magnetic force	$F = \dfrac{\chi}{\mu_0} (\mathrm{grad}\, B)B$	parting of water by magnetic field (Moses effect)
iv) effct of magnetic field on photochemical reaction		yield effect of cage-product and escape-product
radical pair model		

■ Static magnetic fields

Static magnetic fields at residential and environmental levels are very weak, 30~50 μT DC for the earth's magnetic field. In contrast, advanced magnetic resonance imaging (MRI) systems use strong magnetic fields of 1.5 T~8 T.

The biological effects of DC or static magnetic fields are poorly understood. The recognition of the role of the diamagnetic, paramagnetic and ferri- or ferro-magnetic materials in the body helped to unravel the underlying mechanisms responsible for the bioeffects associated with static magnetic fields [1]. The magnetic orientation of biological materials is caused by magnetic torque. Magnetic forces acting on paramagnetic and diamagnetic materials guide the materials along magnetic field gradients.

Photochemical reactions generated by a radical-pair intermediate in solution demonstrate the magnetic field effects that arise from an electron Zeeman interaction, electron-nuclear hyperfine interaction, or hyperfine interaction mechanism including an electron-exchange interaction in a radical-pair intermediate [1-4].
Recent advances in high magnetic field technology have enabled us to study the effects of magnetic fields on diamagnetic materials. For example, the Moses effect or the parting of water was observed after exposure to 8T magnetic fields with a gradient of 50 T/m [5,6].
The magnetic orientation of fibrin and collagen was observed after exposure to high intense magnetic fields [7,8]. The high magnetic anisotropy of biomaterials, which is generated by magnetic torque, caused parallel (fibrin) orientation and perpendicular (collagen) orientation of biomaterials to the magnetic field. The magnetic orientation of red blood cells [9], osteoblasts [10], neural, glial and endothelial cells, smooth muscles, and cow sperm have also been observed.
The redistribution of dissolved oxygen (paramagnetic molecule) in water was observed after exposure to magnetic fields of up to 8T with a gradient of 50T/m [11].
Photochemical reactions by radical pairs in solutions can also be modulated by magnetic fields of 10 mT~1T when the singlet-triplet intersystem crossing is perturbed [12].
Magnetic field effects on enzymatic activity or biochemical reactions in living systems, however, have not been observed.
The effects of static magnetic fields of Tesla order were observed as follows:

i) Embryonic development of *Xenopus laevis*-no apparent teratogenic effects after exposure to 8T magnetic fields for several hours [13].
ii) No enzymatic effects of catalase under 8T magnetic fields [14].
iii) Decrease in skin blood flow, body

temperature, blood pressure, and heart rate of rats exposed to 8T for 20 min. Accelerated evaporation of moisture from the skin by magnetic fields [15].

iv) Magnetic orientation of collagen, fibrin, red blood cells, endothelial cells, and osteoblasts under 8T magnetic field exposure [16].

v) Parting of water by magnetic fields: Moses Effect at 8T, 50 T/m. (diamagnetic water)[5,6]

vi) Blocking of gas flow by magnetic fields: Magnetic Curtain at 1T, 100 T/m. Quenching of combustion; quenching of burning candle flame by magnetic fields – 1.2T, 300 T/m. Magnetic curtain is formed by paramagnetic oxygen during exposure to magnetic fields [17-19].

vii) Redistribution of dissolved oxygen concentration by 8T, 50T/m [11].

■ ELF and low frequency electromagnetic fields

Extremely low frequency (ELF) electromagnetic fields at residential levels are weak, 0.2-20 μT at 50-60Hz AC magnetic fields. Electric industrial equipment and consumer electronic appliances leak mT order of magnetic field at various frequencies from DC to over 100 kHz.

If a living body is exposed to time-varying magnetic fields, eddy currents can be induced in the body. Due to the electrical properties of cell membranes, the induced eddy currents at low frequencies stimulate excitable tissues such as nerve and muscle. For example, human subjects experience magnetophosphene, a visual sensation caused by 10mT AC magnetic fields at 20 Hz [20], at an estimated current density of 1μA/cm^2 [21].

A rapid decrease in skin blood flow of a fingertip was observed when a human hand was exposed to AC magnetic fields of 32mT at 3.8k Hz [22]. This phenomenon is understood by the secondary effect mediated by the nervous system. The sensory receptors of the skin were excited by the eddy currents, and the afferent nervous activity produced the alerting stage of the defense reaction which resulted in an elevated vasoconstructor tone. The estimated current density for the skin receptor excitation was 0.6 mA/cm^2.

Below threshold stimulatory effects on nerve excitation are still unknown. The possible biological effects of ELF fields at residential levels (μT order) are defined by non-stimulatory effects. Many papers have reported on this area [23-26], however, previously reported papers on non-stimulatory effects contain contradictory results.

Many models and hypotheses for the ELF bioeffects have been reported which include, the membrane noise model, the chemical reaction rate modulation model, the calcium ion inflow model, the calcium ion binding to calmodulin model, the cyclotron resonance model, the paramagnetic resonance model, the free radical model, the magnetite particle model related to pressure-sensitive ion channeling, the signal transduction models, the melatonin secretion and breast cancer hypothesis. The details of the mechanisms are still unknown.

■ Pulsed magnetic fields

Pulsed magnetic fields are used in medical applications such as transcranial magnetic stimulation (TMS) and magnetic resonance imaging (MRI).

Pulsed magnetic fields can induce eddy currents in the living body. Transcranial magnetic stimulation of the human brain requires pulsed magnetic fields of 1-2 T for a duration of 0.1-0.2 ms [27,28]. When the induced eddy currents exceed the threshold for nerve excitation, the brain can be stimulated transcranially. When a figure eight coil is positioned on the surface of the head, induced eddy currents create two vortices that merge at a point beneath the intersection of the figure eight [29]. Computer simulations showed that the current density at the merge point was three times greater than that in the surrounding areas. Hence, localized stimulation was attained.

Localized TMS with a figure eight coil has enabled us to stimulate targeted areas of the cortex within a 5 mm resolution [30]. For example, the selective TMS of the motor cortex related to the hand area caused muscle responses from each finger of the hand. In order to investigate motor-nerve function, the motor evoked potentials (MEPs) are recorded from the peripheral muscles that respond to TMS of the target area, which innervates the corresponding muscles [31,32].

Computer simulations also show that the nerve tissues of the brain are stimulated by induced electric fields of 500 V/m – 1600 V/m, which corresponds to the induced current densities of 10 mA/cm^2 –32 mA/cm^2, where the electrical conductivity of the brain is 0.2 S/m. For neuronal excitation, a negative peak of the spatial gradient of the induced electric fields, the activating function, contributes to the depolarization of the nerve cells in the brain.

TMS is useful not only for measurement and diagnosis, but also for the treatment or potential cure of mental illness and central nervous system diseases such as depression, schizophrenia. The use of repetitive TMS (rTMS) has further advanced these types of medical applications even though rTMS is considered a potentially high-risk procedure [33].

MRI techniques have become important tools in medicine and biology. MRI systems use transient or rapid changes of gradient-coil magnetic fields. The rapidness of the transient magnetic fields is defined by dB/dt, where B is the magnetic flux density. Advanced MRI systems such as echo planar imaging (EPI) systems and functional MRI (fMRI) require a high dB/dt value to obtain MR images in a short period of time, around 5-20 images/sec. In this case, it is imperative to assess the potential hazards of the stimulating effects on excitable tissues by the magnetically induced eddy currents [34].

In EPI systems, dB/dt waveforms show a train of rectangular pulses, because trapezoidal waveforms of magnetic fields are generated through gradient coils. The ramp time of the trapezoidal magnetic fields is the duration of the current pulse that is induced in the human body. The International Electrotechnology Commission (IEC) standard is based on the threshold for nerve and muscular stimulation by dB/dt and the ramp time . For example, the normal operating mode is dB/dt ≤ 20 T/s for ≥ 0.12 ms.

A threshold of 80 – 100 T/s was observed for sensation in the middle of the forehead when a human head was exposed to pulsed gradient magnetic fields generated by a train of 64 trapezoidal pulsed currents, which produced rectangular dB/dt pulses with a duration of 200 s [35].

Pulsed magnetic fields of T – mT order are widely used in therapeutic applications such as bone growth, osteoporosis treatment, wound healing, and cell proliferation. The mechanisms, however, require further clarification.

■ Radio frequency electromagnetic fields

With the ever-increasing worldwide use of mobile phones in recent years, some social concerns and anxieties have been raised about the possible biological effects of electromagnetic waves (EMW) in the ultra-high-frequency (UHF) range (i.e., 300 MHz – 3 GHz). High intensity EMW exposure in the UHF range generates heat, which can cause thermal damage to the brain. However, the effects of exposure to EMF of sufficiently low-intensities, which does not elevate the brain temperature, are yet to be clarified.

The interaction of electromagnetic field and radiation with biological systems is characterized by the electromagnetic properties of tissue media, specifically, the permittivity according to Maxwell's equations. The permittivity of biological materials displays unique dependence on frequency [36].

The complex permittivity or the dielectric constant and conductivity is given by $E_r = E'_r - jE''_r$, where the dielectric constant, $E = E_0E'_r$ and the conductivity, $\sigma = \omega E_0 jE''_r$. At the high frequency ranges used in mobile phones, the electrical conductivity, σ, i.e., the imaginary part of the complex permittivity, consumes energy. The possible biological effects of rf fields are discussed in terms of a specific absorption rate, SAR[w/kg]. The SAR = σ E/ρ, where E is the induced electric field and ρ is the density of the tissues.

The International Commission on Non-Ionizing Radiation Protection(ICNIRP) issued a safety guideline for the rf fields used in mobile phones. Several countries in the world including Japan have the same guideline as ICNIRP, which states that the average SAR $\leq$ 2W/kg for the brain for 6 min. In a previous study, Tsurita et al. reported that the thermal effects of microwaves caused an increase of the permeability of the blood brain barrier (BBB) of male Sprague Dawley rats due to 1439 MHz Time Division Multiple Access (TDMA) exposure, as used in cellular phones. In this study the rats were divided into four groups; group 1, brain average SAR 0.99 W/kg, 1h/day, 4 weeks exposure, group 2, brain average SAR 7.5 W/kg, whole body average SAR 1.7 W/kg, 4h, one time exposure, group 3, brain average SAR 2 W/kg, whole body average SAR 0.25 W/kg, 1h/day, 4 weeks exposure and group 4, brain average SAR, 25 W/kg, whole body average SAR, 4.5 W/kg, 1h/day, 1 day exposure. The permeability of the BBB was evaluated by the Evans blue method and immunostaining for albumin method. The morphological changes in the cerebellum were also investigated by assessing the degeneration of Purkinje cells and the cell concentration in the granular layer. No significant increase of the BBB permeability and no morphological changes were observed in groups 1, 2, and 3. However, an increase of the permeability of the BBB resulted when the brain average SAR was 25 W/kg as a result of the thermal effects of the exposure [37].

Yamaguchi et al. evaluated the effects of 1439 MHz TDMA fields on the retainment and acquisition of the reference memory of rats using a food-rewarded T-maze task. Sprague Dawley rats were divided into four groups, EM (7.5), brain average SAR 7.5 W/kg, 1h/day, 4 days exposure, EM (25), brain average SAR 25 W/kg, 45 min/day, 4 days exposure, sham control group, and cage control group. No significant effects on the reference memory performance of rats were observed due to high frequency electromagnetic wave exposure without thermal effects for one hour per day for four days at a brain average SAR of 7.5 W/kg and a whole body average SAR of 1.7 W/kg. However, deficits in reference memory acquisition was observed due to high frequency electromagnetic wave exposure with thermal effects at an average brain SAR of 25 W/kg for 45 minutes per day for four days. High frequency electromagnetic wave exposure at levels much stronger than emitted by cellular phones does not affect either the permeability of the BBB or the memory and learning processes of rats when there are no thermal effects [38].

Many models and possible mechanisms have been proposed to explain the non-thermal effects of rf fields on biological systems. There are ten past and ongoing studies in Japan to clarify the mechanisms, which include the following:

1) neurological effects
2) mice skin cancer promotion
3) in vitro studies on genetic effects
4) in vivo study on the microcirculation of rat brain
5) two year national toxicology program (NTP) study of brain tumors of rats
6) epidemiological link between cellular phone use and tumor growth
7) effects on the permeability of the blood-brain-barrier (BBB) of rats
8) effects on learning and behavior
9) study of microwave hearing
10) in vivo study on eyes exposed to pulsed microwaves

Further studies must be conducted to clarify the mechanisms of non-thermal effects in biological systems.

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REVIEW OF MOBILE PHONE EMF STUDY

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■ Abstract

In this paper, key issues of biological research in mobile-phone frequency band and relevant research activities in Korea are described.

■ Introduction

The mobile phone users reach 28 millions as of July 2001, which is about 62 % of whole population in Korea. Identifying links between cancer and environmental exposure of any kind is surprisingly difficult because of the absence of a single cause of cancer and for a variety of other reasons. Even if mobile phones had no connection to cancer, thousands of users would develop brain cancer every year, and the hundreds of millions of people around world use mobile phones. There are several other diseases under debates which are reported as resulting from RF exposure including mobile phones. Investigation of health effects of cellular phones requires carefully designed studies including accurate exposure assessment. Measurement standard for compliance test to existing regulations are also important, but not fully developed yet.

In this paper, key issues on EMF exposure in mobile phone frequency band and relevant research activities in Korea, including guidelines, biological studies, epidemiological studies, dosimetry, SAR reduction techniques, measurement of EMF exposure environment, will be summarized briefly.

■ Key issues of biological research

Exposure limits for mobile phone of most of the organizations and countries are based on well-understood thermal effect, that is a temperature rise in human body due to exposure from strong EMF source. In spite of that, there are a lot of controversies on possible health effect of low-level exposure. Because of the gaps in knowledge on health effect of long-term low-level exposure, WHO's International EMF Project are focused on biological effects of long-term exposure in 900-2000 MHz frequency band used in mobile or cellular phone systems with exposure levels lower than exposure limits, which include cancer-related studies, studies on changes in hormone levels, memory loss, neurodegenerative disease, effects on the ear and eye, etc.

Currently the guidelines for mobile phones in most of the countries are given by local exposure limits. The limits are, however, not harmonized yet. While those of Korea, IEEE/FCC in U.S.A. and Canada are 1.6 W/kg, 1 g averaged, those of Europe and Japan are 2.0 W/kg, 10 g averaged. The standard procedure for compliance test to these guidelines are under development in IEEE SCC34 and CENELEC, and to derive reproducible test procedure more researches are required.

In Korea, after a comprehensive review of published literatures with scientific credibility, KEES(Korea Electromagnetic Engineers Society) published recommendation on exposure limits which is based on ICNIRP guidelines in 1999. In 2000, in order to protect general public from EMF exposure MIC(Ministry of Information and Communication) announced three guidelines: Guidelines for human protection from EMF exposure in which local SAR limit for mobile phones are included, Guidelines for measurement of electromagnetic field, Guideline for measurement of SAR. The SAR limit for mobile phones is 1.6 W/kg, 1 g averaged, which is the same as FCC as mentioned before. This regulation for mobile phones will be effective from January 1, 2002.

In parallel with this, a large research project called the Korea EMF Project has been launched officially last year, and biological studies, epidemiological studies, studies on dosimetry, etc. are currently in progress. Main research topics follow the research agenda of the International EMF Project, and details will be described in the following sections.

■ Research activities in Korea

The EMF research in Korea was started in 1997. During early phase of research, we focused on literature survey, dosimetry in mobile phone frequency, ELF animal studies, assessment of EMF environment. With the beginning of the Korea EMF project last year, biological researches on mobile phone EMF have been started, including development of relevant exposure system. *In vitro* studies and epidemiological studies are currently on-going, and animal studies for local and whole-body exposure condition will be performed next year.

Special study group on bioelectromagnetic was established in 1996, and "Workshop on Biological Effects of EMF" has been held every year. This study group has also performed studies on exposure limits, measurement method for EMF and SAR , assessment of health effect, and risk communication, in addition to biological studies and dosimetry.

Biological study

We have established a five-year research plan for research items and priorities considering the available research funds, in reference to WHO's International EMF Project. In order to evaluate directions and results of researches, a Research Evaluation Committee consisting of experts are organized.

In vitro studies in cellular and PCS frequency band are in

progress. For those experiments, exposure systems were developed for frequencies of 848.5 and 1,765 MHz. Rectangular cavity type was selected for high power-efficiency, and is operated in TE_{102} mode. It is cooled by water circulation, and CO_2 concentration in exposure system is maintained by external incubator(VS-9108MS incubator, Vision Comp.). The signal sources are exactly the same as real CDMA sources, and exposure levels and exposure time schedule can be controlled electronically using PC.

Some details of *in vitro* experiment for investigation of acute effects of 1,765 MHz RF can be summarized as follows. Two kinds of human cells(Jurkat human T lymphomia cell and WI-38 human fibroblast) and two kinds of mouse cells(DO11.10 mouse T cell hybridoma and C3H10T1/2 mouse fibroblast) are exposed at 1.5 W/kg and 75 W/kg SAR for 30 min. and 12 hrs. The following results were observed for exposure level of 75 W/kg for 12 hrs. Main results are as follows:

1. In immune cells of human and mouse, growth rate was reduced during exposure.
2. Cell growth similar to a normal cell was observed up to 72 hrs. after exposure.
3. Within 72hrs. after exposure, the growth rate of fibroblast and immune cell of human and mouse was not increased.
4. No chromosome abnormalities in human Jurkat cell were observed when examined by karyotyping.
5. In mouse fibroblast cell, actin polymerization was increased by EMF exposure, and it seems that stress response was induced by EMF.

From these results, we may conclude that EMF does not cause any direct short-term effect on chromosome, but can cause stress response and reversible suppression of cell growth.

Epidemiological study

A descriptive epidemiological study to investigate possible health effects of mobile phone EMF was performed last year. The scope of this research is to perform an ecological correlation study using data bases on medical insurance, national death record, cancer registration record, and to evaluate the association between cellular phone use and reported specific symptoms like headaches, dizziness, nausea, eye pain, fatigue, insomnia, concentration difficult difficulty, ear irritation, etc., by surveying more than 1,000 mobile phone users.

We found that there are no statistical correlation in brain cancer and breast cancer, but a clear statistical correlation between thyroid cancer and mobile phone use was observed. We cannot conclude, however, that this correlation results from a cause-effect relation. In order to confirm this result, further analytical epidemiological researches like case-control study or cohort study are required. In addition, confounding factors must be properly controlled and a larger number of samples are needed for statistical validity.

Three exposure measures of hours per day, years of use and lifetime cumulative hours were used, and reported specific symptoms were compared with those exposure measures. Persons who experienced symptoms, such as dizziness, nausea, eye pain, ear irritations symptom, fatigue, insomnia(sleep disorder), heat sensation in cheek, showed higher exposure level. In addition, positive dose-response relation was observed for dizziness, nausea, eye pain, and heat sensation, when compared with cumulative exposure level.

These dose-response relations were obtained by correcting the effects of age, sex, average hours of sleep per day, usage of computers, sensitivity in characters, forgetfulness. Some correlation between symptoms and EMF exposure was found, but cause-effect relation is not clear because this research is just a cross-sectional research. To confirm this relation, additional analytical epidemiological study needs to be performed.

Dosimetry

In order to evaluate the amount of exposure due to mobile phones quantitatively, numerical and experimental studies in dosimetry have been performed. Both methods for SAR assessment have advantages and disadvantages. Experimental methods utilize a human phantom, which consists of a dielectric shell of human shape and fluid with dielectric properties similar to human tissue. Electric field is measured using small isotropic electric field probe, and then SAR values are estimated from the rms electric field. With the rapid improvement of MRI and computer technology, development of numerical model which are very close to realistic human body becomes possible, and thus numerical method for SAR calculation experiences a big break-through.

Currently CENELEC (European Committee for Electrotechnical Standardization) and IEEE (Institute of Electrical and Electronics Engineers) are preparing SAR measurement standards for mobile phone, and IEEE Standard Coordination Committee 34 Subcommittee 2 is working on standardization of numerical methods in addition to experimental method.

In Korea, "Committee for Standardization of SAR Evaluation" was organized, and researches on SAR assessment technology for mobile phones were performed during last several years. From the results, guidelines for SAR measurement method was prepared and MIC announced it early 2001 as mentioned before. Researches on numerical and experimental assessment of SAR are still going on. Main research topics include extrapolation method in SAR measurement, design and fabrication of SAR measurement probe, measurement of SAR reduction components/substances and analysis of relevant errors[5], development of human phantom[6], development of domestic numerical model for human body[7], tissue-averaging method for assessment of local SAR[8], changes in SAR due to head size[9], uncertainty analysis, etc. A few results are described below.

The automated SAR measurement system setup has been developed in ETRI(Electronics and Telecommunications Research Institute). This setup consists of a robot, E-field probe, a shell phantom, tissue simulating liquid and measurement software. A model ET3DV5R E-field probe of Schmidt & Partner Co. is used to determine the internal electric fields. The positioning repeatability of the 5-axis robot system (Samsung co., Korea) moving the E-field probe is within $\pm$ 0.02 mm. The software controls the robot and processes the measured data.

The recommended test positions for mobile phone measurement are slight different from each other until the

end of 2000. While measurement position is touch position in FCC, the angle α between reference line and center line can be chosen by manufacturers in Japan, which is rather relaxed compared to FCC. In contrast, CENELEC recommend 4 test positions, and SAR value for a mobile phone is determined from the highest one. Recently CENELECE and IEEE SCC 34 SC2[5] specifies touch position and tilt position as the test position, which is expected to be reflected in U.S.A., Japan, IEC, etc. In Korea, worst-case position was adopted as the test position in guidelines for SAR measurement. SAR values different test positions were measured using the measurement system mentioned above, and the results were compared. We found that touch position and tile position suggested by CENELECE and IEEE SCC 34 SC2 represent worst-case exposure condition. The values for tilt position were higher because the location of antenna is closer to phantom head.

In numerical calculation of SAR, anatomical models are widely used. However, there are difficulties in averaging for a tissue volume of cubic shape, because the outer shape of a realistic human body has a variety of different curvatures, and empty spaces like auditory canal or nasal cavities exist in a human body. A method of taking contiguous volume has been proposed, as in ICNIRP guidelines. If the proposed method is used, SAR calculation at an arbitrary point in a body is possible, and we can resolve the problem of a lower SAR values resulting from a tissue volume of cubic shape.

SAR values in human head show a big difference depending on head shapes. In order to calculate SAR values for a mobile phone accurately, we need to use an exact anatomical model for a given species and ages. We thus developed a head model with 1mm×1mm×1mm voxel size, based on MRI and CT images of a volunteer with the standard height and weight of Korea, and a whole-body model with 3mm×3mm×3mm voxel size is under development. For the classification of tissues, FCC's recommendation[12] was used.

Local SAR values for different head sizes and shapes were calculated using the FDTD method for mobile phone frequencies of 835 and 1,765 MHz. The major findings can be summarized as follows:

1. The deeper EM energy penetration into head occurs at 835 MHz than at 1,765 MHz, but the stronger deposition at the surface at 1,765 MHz is shown.
2. The head geometry strongly influences on localized SAR evaluation at 835 MHz and the trend of increasing localized SAR for a larger model have been observed.
3. However, The head geometry is no longer a factor influencing on the localized SAR at 1,765 MHz and the SAR results are very constant.

At present, current SAR evaluations by the FCC are performed only with large adult phantom. Our results support that the FCC considers the worst case of the phantom because only localized SAR is evaluated for mobile phones. However, the safety guidelines are based on the whole-body averaged SAR that brings about the biological hazard due to temperature rise. Therefore, the greater whole-head averaged SAR in a smaller head model may not be disregarded and these results can be used to investigate differences of biological effects according to human species and ages.

SAR Reduction Technology

Various techniques to reduce EMF absorbed into human body, using proper arrangement of antenna, RF absorbers, etc., are under development. A few results are described below.

A smart technique has been proposed for reducing RF energy absorption into head. The main idea is to reduce the amount of radiation in the direction of head, by properly arraying two conventional helical antennas. Radiation patterns of a single conventional helical antenna and proposed array of helical antennas are compared, and it turns out that radiation pattern in other directions are not bad compared to conventional one. Local SARs were measured in phantom for both cases. The results shows that SAR values were reduced approximately by 35 % for 1 g average and 27 % for 10 g average.

A new mobile phone antenna has also been proposed, which has a specially manufactured Mn-Zn cylindrical ferrite bead inside of the helical coil of the antenna. Main ingredients of radio frequency magnetic material are zinc oxide(ZnO) and dioxide manganese(MnO_2), and the percentages of each material are about 16 % and 15 %, respectively. Small amounts of yttrium oxide(Y_2O_3), potassium oxide(K_2O), titanium oxide(TiO_2), sodium oxide(Na_2O), silicon oxide(SiO_2), nickel oxide(NiO) and chrome oxide(Cr_2O_3) are added.

The maximum 1 g SARs with and without the ferrite bead insertion were measured at 824 MHz. The results show that the ferrite bead resulted in SAR reduction of about 20 %, and reflection coefficient increase of about 7 % for the extended antenna. It is expected that it can be utilized for a commercial production.

Measurement of EMF environments

Even though EMF levels around mobile phone base stations are considerably lower than exposure limits, many people are concerned about them. Several measurements were performed before in Korea, but to relieve public concerns about base stations a comprehensive measurement was made 2001, based on Korean guidelines for EMF measurement. Number of measured base stations are 24 in total, 6 stations for each service provider, and equal number of base stations were selected for urban, suburban and rural environments. Isotropic 3-axis electric filed probe(HI-6005) and readout device of Holaday satisfying Korean guideline was used. Frequency range is 100 kHz ~ 5 GHz, and range of electric field strength is 0.5 ~ 800 V/m.

Measurements were made on streets, on rooftops, in inside of buildings, in playgrounds. As can be seen from the figure, for both cases EMF levels are far below domestic exposure limits, which are same as ICNIRP guidelines, and even lower than very conservative exposure limits of Swiss.

■ Conclusions

In this paper, mobile phone EMF studies in Korea are reviewed. Studies in this area were started in late 90's, but

current research activities are quite active, especially in dosimetry and SAR reduction technology, which is driven by rapid increase of mobile phone users and their concerns about possible adverse health effects. With the embarkment of the Korea EMF Project, EMF researches in mobile phone frequency become well organized, research topics and priorities being carefully determined. International cooperations such as the International EMF Project are very important, and we join the variety of international activities currently going on wroldwide. We expect a lot of progress will be made in various areas of mobile phone EMF research in Korea.

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CHARACTERISTICS, DOSIMETRY & MEASUREMENT OF EMF

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■ Abstract

This paper describes characteristics of electromagnetic fields and their interaction with body as a fundamentals of electromagnetic field (EMF) safety issue. It also presents how engineering and physics contribute to this. EMF should be appropriately and precisely characterized when we consider its interaction with body. Dosimetry, which is the quantification of substance interacting with the exposed body, is of quite importance in the exposure assessment for both compliance testing with guidelines and the quality control of researches on EMF effects. The basic concept of these issues is summarized, and some researches mainly performed by the authors' group are presented as examples of researches in this field.

■ Introduction

When we discuss the biological and health effects of electromagnetic fields (EMF), it is often the case that biology and health science is of the primary concern, and engineering and physics are of the second concern. It is important, however, to remember that we are dealing with interaction between electromagnetic field and body. The physical interaction should first be characterized and quantified. Then substantial phenomena that should occur in tissue or cells are better realized. With all these quantitative description we could better define the biological and health effects that are subsequently observed. The aspects of engineering and physics are no less important than biology.

In the practical situations it is required to establish reliable and reproducible measurement procedures to perform the assessment of compliance of electromagnetic environment with the guidelines properly. It is also important to understand electromagnetic phenomena to avoid artifacts due to unwanted coupling between objects and measuring instruments. We sometimes encounter situations where the measurement of external field is not appropriate to determine the compliance of exposure with the guidelines. Near-field exposures are such the cases. In these cases we need to quantify electromagnetic phenomena in the body. This technique is called "dosimetry". Exposure to EMF from mobile telephone is the typical case where dosimetry should be applied in the hazard assessment.

Engineering plays a crucial role in experiments to investigate biological effects of EMF. Electromagnetic fields must be characterized as precisely as possible. We must characterize not only the incident fields but also internal fields in the biological specimen. Dosimetry of exposure setup is one of the key issues that determine the quality of experimental studies.

In this paper we will describe these aspects of engineering and physics related to the safety of EMFs to clarify the physical concepts as well as their important roles in this issue.

■ Characterization of EMF [1]

1 .Variables to be determined

The electromagnetic field is characterized by a pair of vector fields of electric field **E** [V/m] and magnetic field **H** [A/m] (or **B** [T]). Each vector field has three time varying components in space; hence we need to determine six functions of time at each point in space to characterize the field completely. It is obvious that the characterization in this complete sense is far from practically achievable. Fortunately the components of these vectors are not independent as they are governed by Maxwell's equations. Hence we just need to specify fewer variables that are practically achievable. However it is worth recognizing the fact that the EMF in general can not be characterized completely in a simple manner in the strict sense.

2. Frequency and waveform

Any functions can be decomposed to a summation of sinusoidal functions of arbitrary frequencies with appropriate phase. This fact is the basis for the frequency domain approach. Thus biological effects are often discussed in frequency region.

Power frequency electromagnetic fields are almost pure sinusoidal waves at 50/60 Hz, and waveforms of radiofrequency (RF) communications are relatively narrow band relative to their carrier frequencies. However we should note that the waveforms of actual electromagnetic fields are not pure sinusoidal waves.

3. Polarization

The orientation of field vectors **E** and **H** are another important characteristic. It is called "polarization". It is well known that RF electromagnetic field with E-field parallel to the body axis shows resonant characteristics at around the frequency where the body height is the half-wavelength. The current density induced by time varying magnetic field is also dependent on the direction of H field. The larger the cross sections of body perpendicular to **B**, the larger the induced current density. The orientation of field relative to the exposed object is very important when we consider the coupling of electromagnetic fields with biological bodies. Figure 1 shows the directions of fields that shows largest coupling with body and the direction of induced current densities.

We should note that the polarization is not necessarily constant with time. Two field vectors with different

directions superpose to make a total field as a result of the vector summation. If the orientations of these vectors are different and have different phases, the orientation of the total vector is not constant but moves elliptically. Elliptically polarized fields are found in the magnetic field beneath the three-phase power transmission lines. Satellite communications also employ circularly polarized microwaves.

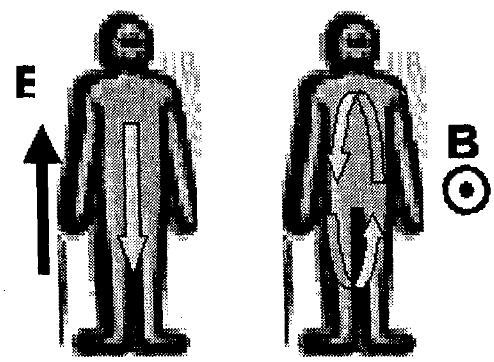


Fig. 1. Orientation of **E** and **B** fields which have the maximum coupling with body and induced current.

■ Measurement of EMF

1. Basic principle

Electric and magnetic fields can be measured by using antennas that respond to the field of concern. Electrical gap or infinitesimal electric dipole detects the electric field of the component parallel to the dipole. A small loop or an infinitesimal magnetic dipole responds to the magnetic field of the component parallel to the dipole moment or perpendicular to the loop face. Larger elements can have higher sensitivity, but the response could be dependent on frequency. A parallel plate is one of the commonly used sensors in electric field measurement, which is equivalent to an array of electrical gaps. It should be noted that existence of metal can disturb fields due to the scattering of field by the metal.

Devices to detect electric and magnetic fields without metallic antenna have also been developed. Pockels effect is used for electric field sensors. Hall effect is used for magnetic field sensors. These sensors are not sufficiently sensitive to the fields for the purpose of hazard assessment in common environment, however.

2. Polarization

The sensor elements respond only to one direction of field components. Combined elements with orthogonal directions are often used to detect three dimensional components simultaneously. This type of sensors is called an "isotropic sensor". Isotropic probes for the purpose of hazard assessment of EMF are commercially available both for E and H fields. Figure 2 shows an example of the isotropic E-field sensor.

3.3 Measurement method

A number of instruments are commercially available which are specially designed for measuring electric and magnetic fields for hazard assessment. These instruments provide measured values directly. However it is important to note that the figures on the display are not always correct values of interest.

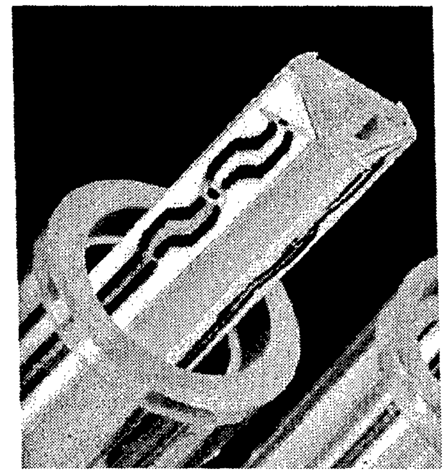


Fig. 2 A picture of isotropic implantable probe

The artifacts can arise from inappropriate orientation of the cable, disturbance of the field by the presence of body, coupling of probes with metallic objects, and so on. Magnetic field probes could respond to electric field erroneously, and vice versa. There are a lot of items to be considered in the field measurements. The practical procedures of the measurement have been issued as standard procedures elsewhere. [2][3]

■ Dosimetry

1. Dose metric

Dosimetry means the metrology of dose. "Dose" is defined by "the amount of a substance we are exposed to or come in contact with". Here a problem arises; what is the "substance" to be determined in the dosimetry of electromagnetic fields?

There is a consensus as follows[5][6]. Stimulation effect prevails over other possible effects in the low frequency region (up to 100 kHz), where the induced current density **J** [A/m^2] in tissue is the dosimetric quantity. In higher frequencies above 10 MHz up to 300 GHz, thermal effects are prevailing. Specific absorption rate (SAR), which is defined by the absorbed power per unit mass at infinitesimal volume of tissue [W/kg], is the quantity to define the dose at frequencies from 100 kHz to about 10 GHz. Incident power density [W/m] is more appropriate than SAR at frequencies above 10 GHz, where the penetration of EMF into skin is very short. Thermal effects and stimulation effects could overlap each other in the intermediate frequencies between 100 kHz and 10 MHz.

The basic restrictions of guidelines on electromagnetic field exposures are therefore given by these quantities. The induced current density in the low frequencies and the

SAR in high frequencies are the quantities to be determined in the electromagnetic dosimetry when we perform the exposure assessment based on the exposure guidelines.

However we have not been fully convinced that the stimulation effect and the thermal effect are the only mechanisms that can threat human health. Further investigations are still ongoing to explore possible other effects. It is important to characterize the internal electromagnetic quantities in tissue as precisely as possible when we explore possible effects related to unknown mechanisms. In this sense the electromagnetic dosimetry for experimental studies should include the detailed characterization of internal electromagnetic fields in addition to induced current density and SAR.

2. Methods of dosimetry

Induced current density

In the low frequency region, the exposed object is much smaller than the wavelength. In addition magnetic field induced by the current in the body is negligibly small. In this case quasi-static approach is appropriately applied.

Quasi-static analysis of electromagnetic fields including biological bodies comes to solving a Poisson's equation. Theoretical analysis was applied in early works assuming a head or body model with a simple shape such as a sphere. Later numerical methods are mainly applied as the body has an arbitrary shape and heterogeneity in tissue electrical properties. Numerical methods include finite difference method (FDM), finite element method (FEM), boundary element method (BEM)[7]. Those methods assume a voxel model, which allows arbitrary shape and anatomical heterogeneity. Recent progress in numerical technique and computation resources has enabled us to calculate very fine distribution of induced current density in tissue.

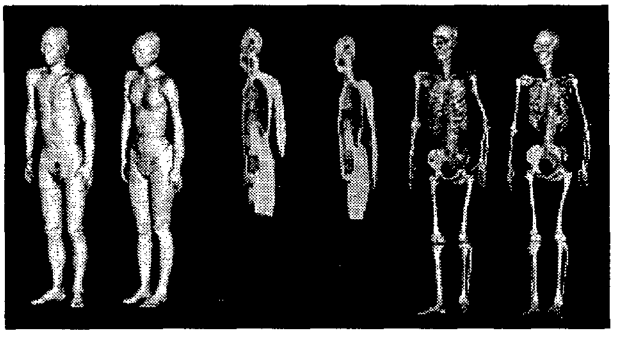


Figure 3 Numerical whole-body human model of male (left) and female (right)

Numerical models of human body have been developed in various institutions. These models are made from the numerical data from magnetic resonance imaging (MRI) or X-ray computerized tomography (CT) images. The resolution is a few milliliters up to sub-millimeters. Figure 3 shows the examples of whole-body male model and female model developed by Kitasato University and CRL in Japan.

Experimental approaches are also attempted to measure induced current densities by electric fields. On the other hand experimental approach is rather minor in magnetic field induced currents. The difference in induced current between E and B (Fig. 1) may be the reason.

SAR

In radiofrequency region, where quasi-static approach can not be applied, the analysis should be based on wave equations derived from Maxwell's equations. The same history of numerical approaches as in the induced current calculations was followed also in RF region[7]. That is, early works were done by theoretical analyses assuming a simple model, followed by numerical techniques with more detailed numerical models. Method of moment (MoM) using a block model was used in early numerical works. The development of the finite-difference time-domain (FDTD) method made an epoch in this field. This method now provides extremely powerful means to numerical dosimetry and is widely used in various purposes in this field. Figure 4 shows an example of numerical calculation including whole-body human model (Fig.3) and a mobile telephone obtained by FDTD method.

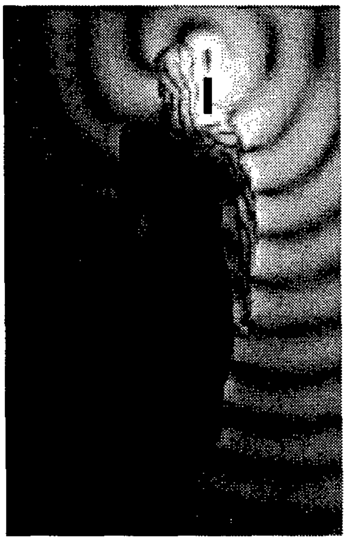


Fig. 4 Calculated electric field in and around a human body obtained by finite-difference time-domain (FDTD) calculation

Experimental approaches are also applied in the determination of SAR. Tissue equivalent "phantoms" are used instead of real bodies in the experimental dosimetry.

Thermographic method directly measures temperature elevation due to absorbed energy in the exposed object to RF. If the temperature rise is abrupt enough to neglect heat conduction, the temperature rise is directly proportional to SAR at any point. Thermographic camera provides a two-dimensional image of temperature rise at once, which directly represents SAR distribution. This method can measure the SAR distribution only on the surface of the phantom. Hence the phantom must be split to reveal the section of interest after exposure to take the thermal image on the surface. The limitation of this method is that extremely high power is required to satisfy the condition

of negligible heat conduction during measurement.

Another experimental approach is the implantable probe method[8]. Miniature isotropic E-field sensors are commonly used. The sensor is immersed into tissue equivalent liquid phantom, and the internal electric field in the phantom is measured. The SAR is calculated from internal E-field by the relationship

$$SAR = \frac{\sigma}{\rho}\left|E^2\right|$$

This method has an advantage of high sensitivity that allows ordinary operation of mobile phones to measure SAR. This is a merit to be adopted as a standard compliance testing of actual mobile telephone devices. A typical sensor is shown in Fig. 4.

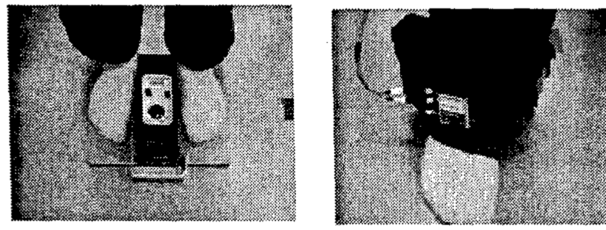
Limb current

It has been known that higher current densities arise in arms and legs of the body exposed to RF fields as these parts are narrow in the section[9]. Figure 5 shows calculated SAR distributions in the grounded body exposed to E-polarized plane wave at 30 MHz (left) and 120 MHz (right). It is obvious that exposure to RF near resonant frequencies causes high SAR in the lower legs.

Fig. 5 SAR distributions in a human model exposed to 30 MHz (left) and 120 MHz (right) homogeneous plane waves with the orientation of E-field parallel to the body axis (E-polarization). Incident power densities are at the reference levels of the guidelines.

The exposure limits in SAR is relaxed in limbs because there is no important organs such as brain or internal organs. However excess SAR in limbs should result in temperature elevation to cause various adverse health effects including thermal injury.

Because of the relatively simple structure of limbs, the SAR in the limb is well correlated with the current flowing in the limb. Reference levels with respect to limb current are provided in the guidelines as an alternative means to estimate the maximum SAR in the limb[4][5].



(a) (b)

Fig. 6 Limb current meters.

Limb current meters specially designed for this purpose are commercially available. There are two types of these instruments. One is flat-bed type (Fig. 6a). Another is current clump type (Fig. 6b). These instruments must be appropriately calibrated to provide reliable values.

■ Mobile phones dosimetry

1. Interaction characteristics

Mobile phones are used in the vicinity of human head. Consequently the radiation structure is very close to the head so that it may tightly interact with the head. The SAR distributions during the use of handheld telephones have been intensively investigated both by theoretical and experimental approaches [8][10].

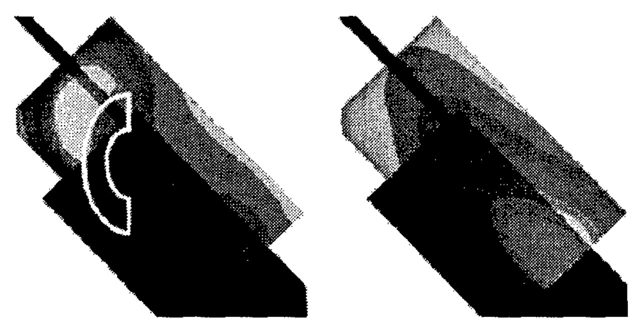


Fig.7 Measured SAR distribution caused by mobile phones in phantom models with (left) and without (right) ear

It is recognized that the maximum SAR appears near the radiating structure where the RF current is maximal. The location of maximum SAR is usually a part of the exposed head near the base of the ear. It sometimes appears in cheek if the current on the chassis is rather large and the device is held close to the cheek. It is also recognized that presence of ear affects the SAR distribution. The maximum value of the local SAR is not significantly affected, however. Figure 7 shows the measured distributions of SAR on a head model with and without a ear.

2. Compliance testing

Exposure guidelines limit maximum local SAR due to exposure by radiation sources close to the body. The limit value is 2 W/kg in any 10 g tissue, or 1.6 W/kg in any 1 g tissue for general public or uncontrolled environment. Former figure is applied in EU and in Japan. The latter is

applied in the USA and in Korea. Regulatory bodies in various countries have decided or are about to decide to request mandatory certification of mobile telephones to comply with the guidelines. The standard procedure for the estimation of the maximum SAR by mobile phones is necessary.
The standards have been deliberated in several standard setting bodies[11]-[14]. Recently agreement on the procedure has been essentially achieved. The method is based on the implantable isotropic E-field sensors with a liquid phantom.

■ Design and dosimetry of exposure setups

1. Role of dosimetry in EMF experiments

Dosimetry plays an important role in the experimental studies to investigate possible effects of electromagnetic fields. Inaccurately designed exposure setup is not only misleading but can be expensive. Once a false positive result is obtained and published by a poorly designed exposure setup, far more sophisticated experiments are required to provide negative results to be accepted as the counterevidence. Inadequacy of the characterization of dose may result in such inconsistency of experimental results.

On the other side, precisely designed exposure setups with good dosimetry can produce robustly consistent results. This could reduce the numbers of specimen required for the experiment, resulting in the reduction of the cost and labor in total. In addition precisely characterized exposure condition allows exploration of the mechanism of interaction.

2. *In vivo* studies

Precise dosimetry is indispensable in recent animal experiments. When we plan an experiment aiming investigation of localized exposure effect, such as for mobile phone exposures, it is very important to achieve the localized exposure condition similar to the actual exposure condition of human body. It is not easy, however, to achieve this condition, as the animals are much smaller than humans.

A criterion to decide localized exposure condition is 20 – 25 times larger maximum local SAR than whole-body average SAR. This criterion derives from the ratio of the guideline figures of maximum local SAR to whole-body average SAR. In the case of human exposure to mobile phone EMF, this ratio is approximately100.
Figure 8 shows an example of localized exposure system for rats using a loop antenna. This system can achieve the desired condition of localized exposure. Similar systems have been developed in several laboratories.

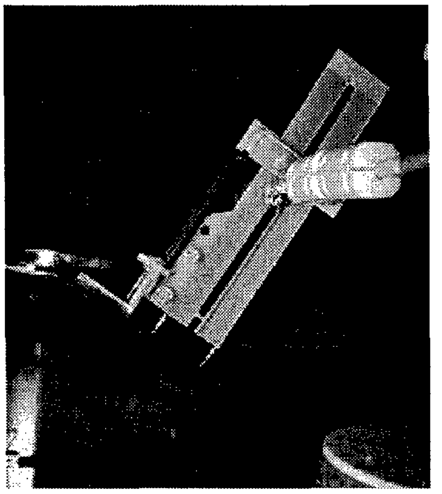


Fig 8 Localized exposure system for rat using a loop antenna

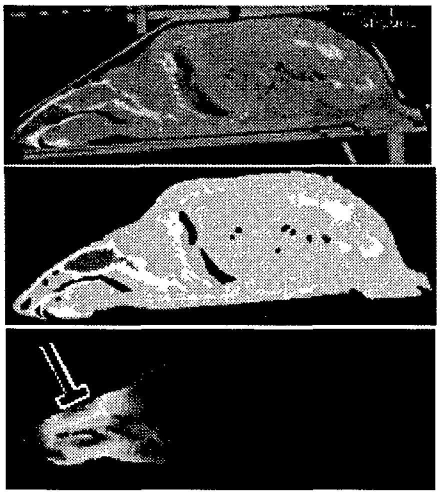


Fig. 9 Exposure assessment of the setup in Fig. 8.
CT image (upper), heterogeneous numerical model (middle), calculated SAR distribution (lower).

■ Microwave hearing

1. Microwave auditory effect

Microwave hearing is an established biological effect specific to pulsed microwaves with high peak power. The mechanism of this phenomenon has been suggested that the microwave pulse generates thermoelastic waves in the head to stimulate auditory system. This hypothesis has been examined theoretically and experimentally .
8.2 Thermoelastic-wave dosimetry
Previous works that have been done to clarify this effect assumed simplified head models. We present here an example of dosimetry which deals with thermoelastic waves as the dose metric of the effect, instead of SAR itself. A human head with a complex shape and anatomical heterogeneity is assumed here (Fig. 10)[15].

First the distributions of specific absorption rate (SAR) in these models were calculated by means of FDTD method for Maxwell's Equation. Then thermoelastic waves were calculated using FDTD method for elastic wave equation.

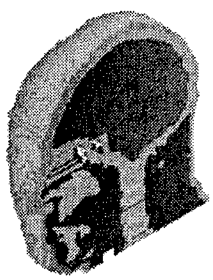


Fig. 10 Anatomically based human head model

Figure 11 shows the reverberation of elastic waves in the head model generated by a single pulse with a duration of 20 μs at 2.45 GHz. The largest stress appeared near the center of the head. The peak stress near cochlea was 7 x 10^{-5} [Pa] or 11 dB for incident plane waves with 1 mW/cm^2 and pulse duration of 20 μs.

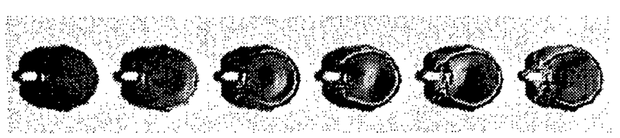


Fig. 11 Thermoelastic waves propagating in the head

■ Concluding remarks

Field characterization, dosimetry, and measurement of EMF are briefly discussed. The authors wish that critical review of studies from the standpoint of engineering and physics should be more emphasized in the quality judgment of biological researches. Improved engineering should reduce the uncertainties that exist in unresolved problems of EMF health issue.

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REVIEW OF HEALTH EFFECTS AND GAPS IN KNOWLEDGE

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■ Abstract

There have been a number of recent reviews of the health effects of various parts of the electromagnetic spectrum. In addition to the reviews under the International EMF Project in Munich in November 1996 and in Erice, Sicily in 1999 on RF fields and the review of static and ELF fields, held in Bologna in June 1997, there have been substantial reviews held by other organizations. Recent RF field reviews include the Independent Expert Group on Mobile Phones (UK, 2000), while reviews on the health effects of static and ELF electric and magnetic fields have been conducted by IARC (June 2001), by the Health Council of the Netherlands (May 2001), and by an expert Advisory Group of the National Radiological Protection Board in the United Kingdom (AGNIR) (March 2001). The results of these reviews will be summarised here and gaps in knowledge identified.

■ Introduction

Electromagnetic field (EMF) sources to which people may be exposed are predominantly in two frequency ranges are currently the main object of concern among the public for their possible effects on human health :

- the extremely low frequency (ELF, < 300 Hz) range incorporating the 50 and 60 Hz frequencies of the electric power supply and of electric and magnetic fields generated by electricity power lines and electric/electronic appliances;
- the radio frequency (RF, microwaves, 10 MHz - 300 GHz) range at which the current wireless communication devices operate, mainly the 900 MHz and 1800 MHz used by GSM mobile phones.

Most research studies devoted to possible biological or health effects of EMF today concern ELF or RF fields. The intermediate range of frequency (300 Hz - 10 MHz) has not yet received enough attention despite the rapid development of appliances such as induction heating devices, anti-theft and remote detection systems. However, a recent WHO review of this area is included.

This review will summarise biological and health effects in the 3 ranges and identify gaps in knowledge that need to receive further research before better health risk assessments can be made.

■ Health hazard: definitions and criteria

Many effects on biological systems exposed to static and ELF fields have been reported. However, the seminar's principal concern was to determine whether these lead to any adverse health consequences. Explicit distinctions were made between the concepts of interaction, biological effect, and health hazard, consistent with the criteria used by international bodies when making health assessments (Repacholi and Cardis, 1997): Biological effects occur when fields interact to produce physiological responses that may or may not be perceived by people. Deciding whether biological or physiological changes have health consequences depends, in part, upon whether they are reversible, are within the range for which the body has effective compensation mechanisms, or are likely, taking into account the variability of response among individuals, to lead to unfavourable changes in health.

WHO defines health as the state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity. Not all biological effects are hazardous. Some may be innocuously within the normal range of biological variation and physiological compensation. Others may be beneficial under certain conditions, and the health implications of others may be simply indeterminate. Uncertainty adds to the unacceptableness. Health hazard was generally defined to be a biological effect of field exposure outside the normal range of physiological compensation and adverse to a person's well-being.

■ ELF Fields

Most public exposure to ELF fields comes from electrical appliances, household wiring, and AC transmission and distribution lines. Recent reviews on the health effects of static and ELF electric and magnetic fields conducted by IARC at a working group meeting in June 2001, by the Health Council of the Netherlands (2001), and by an expert Advisory Group of the National Radiological Protection Board in the United Kingdom (AGNIR, 2001).

Interaction mechanisms

A well known mechanism of interaction of ELF fields with biological tissues is the induction of time-varying electric currents and fields. At sufficiently high levels, these can produce direct stimulation of excitable tissues such as nerve and muscle cells. At the cellular level, the interaction induces voltages across the membranes of cells sufficient to stimulate nerves to conduct or muscles to contract. This mechanism accounts for the ability of humans and animals to perceive electric currents in their

bodies and to experience electric shocks. Other mechanisms have been proposed, but there is little evidence to support them.

Electric fields

External ELF electric fields induce time varying electric charges on the surface of the body. The magnitude and distribution of the charges depend on the body shape and its location and orientation relative to the field and ground plane. In addition, electric fields, electrical polarization changes, and currents are induced inside the body as a result of time variation of this surface charge density. Charges fixed on internal molecules polarize and depolarize as the field changes. Since time variation in the ELF range is slow compared to the ability of charges to move, the fields and currents generated inside the body from this source are very small. The induced current density distribution depends on the electrical properties of the tissue and varies inversely with the body cross section. Typically, the strength of the internal electric fields is less than 10^{-6} of the external field.

Magnetic fields

The induced current density is proportional to the rate of change of the magnetic flux density. For sinusoidal applied fields, the induced fields and currents are linearly dependent on frequency. The magnitude of the currents induced by pulsed magnetic fields will depend on the rise and fall time of the pulse. The highest current densities are induced in peripheral tissues, since these have the largest inductive loop radius in the body. However, tissue inhomogeneity and orientation of the body to the field will affect the current path. In general, the electric field induced in peripheral tissues by a horizontal magnetic field is approximately 1.5 times that induced by a vertical magnetic field of similar magnitude. Currents circulating from head to foot due to a horizontal magnetic field will be high in the neck because its small cross section concentrates the flow.

For a human with torso radius of 0.15 m and tissue conductivity of 0.2 S/m, a 50 Hz magnetic field parallel to the long axis of the body will induce a current in the tissue periphery of about 5 A/m^2 per tesla. Since current density is proportional to body radius, current density values can be used to scale between animal and human exposure. Typical induced currents and fields for 1 μT, 60 Hz uniform magnetic field exposure of mice, rats and humans are in the range of 0.1~0.4, 0.3~1.3, and 1~20 $\mu A/m^2$, respectively.

■ ELF biological effects

Laboratory studies

Above about 0.1 mT, a variety of studies have demonstrated effects *in vitro* on ornithine decarboxylase (ODC) activity. Not all replication attempts have succeeded, however. Many other biological effects have been reported above about 1 mT. How magnetic field exposure produces such effects is unknown. For most effects, such as those reported on genotoxicity, intracellular calcium concentrations, or general patterns of gene expression, convincing and reproducible results have not been observed. None of the *in vitro* effects are necessarily indicative of an adverse health effect. Without knowledge of the mechanisms involved, effects observed at high field strengths cannot be extrapolated to lower fields, since the mechanisms may be different.

While there is no convincing evidence that ELF fields cause cancer in animals, only a limited number of studies have been conducted to test this hypothesis. Some recent studies suggest a positive relationship between breast cancer in animals treated with carcinogens and ELF magnetic field exposure at approximately 0.02~0.1 mT. The importance of these findings needs to be investigated further. Currently available data do not provide convincing evidence of adverse effects from exposure to power frequency fields on reproduction or development in mammals. There is evidence of behavioural and neurobehavioural responses in animals, but only following exposure to strong ELF electric fields.

Neuroendocrine changes are associated with exposure to ELF magnetic fields, but these alterations have not been shown to cause adverse effects in animals. Some studies suggest magnetic fields of strength between 0.01 and 5.2 mT might inhibit night time pineal and blood melatonin concentrations in experimental animals. However, such effects have not been demonstrated in humans.

Human laboratory studies

Perception

Exposure to ELF electric fields can result in field perception as a result of alternating electric charge induced on the surface causing body hair to vibrate. Most people can perceive electric fields greater than 20 kV/m, and a small percentage of people perceive field strengths below 5 kV/m. In two well controlled studies, humans were unable to perceive magnetic fields at levels up to 1.5 mT.

During exposure to ELF magnetic fields above 3~5 mT, volunteers experience faint visual flickering sensations or magnetophosphenes. The threshold current density in the retina for induction of magnetophosphenes is about 10 mA/m^2 at 20 Hz, which is well above typical endogenous current densities in electrically excitable tissues. Higher thresholds have been observed for both lower and higher frequencies.

Cardiovascular

Several reports indicate that ELF fields influence the cardiovascular system. Exposure of human volunteers to combined 60 Hz electric and magnetic fields (9 kV/m, 0.02 mT) resulted in small changes in cardiac function. Resting heart rates were found to be slightly but significantly reduced (about 3~5 beats/minute) during or immediately after exposure. This response did not occur with exposure to stronger (12 kV/m, 0.03 mT) or weaker

(6 kV/m, 0.01 mT) fields and was reduced if the subject was mentally alert. In these double blind studies, subjects were unable to detect the presence of the fields. While continuous exposure to combined electric and magnetic fields at 9 kV/m, 0.02 mT slows the heart, intermittent exposure can result in both slowing and increasing heart rate. None of the effects on heartbeat exceeded the normal range. No obvious acute or long term cardiovascular related hazards have been demonstrated at levels below current exposure standards for ELF or radio frequency fields.

Spectral analysis of electrocardiograms indicated that intermittent exposure to ELF reduced power in the Fourier spectrum at frequencies associated with blood pressure and thermoregulatory control mechanisms, and increased the power associated with respiration. These results were replicated in another sample of volunteers using a different experimental design. In contrast, a third study by the same group failed to show any effects on heart rate variability when subjects were exposed continuously rather than intermittently to the same ELF field. The patterns of heart rate variability observed in the above studies are similar, but not identical to, the pattern found to be predictive of sudden cardiac death.

Hormone and Immune System Effects

No changes in blood chemistry, blood cell count, blood gases, lactate concentration, skin temperature or circulating hormones have been observed. Field related suppression of the hormone melatonin has been proposed as a mechanism for the relationship between exposure to magnetic fields and increased cancer risk reported alterations in melatonin production in people sleeping at home under electric blankets, although all subjects did not show melatonin suppression. Suppression of melatonin has also been reported in studies of Finnish garment workers, electric utility workers, and VDU workers. In contrast, well-controlled laboratory studies report mostly negative results. Some laboratory studies, however, have reported positive results.

Two recent French reports indicate that acute exposure for one night to a linearly polarized magnetic field at 10 μT has no effect on hormonal or immune parameters in healthy male volunteers. No published reports have examined possible differential effects in women, possible influence of longer exposure or of altering field polarization.

Epidemiological studies

The following are the concluding remarks from the report of a Working Group formed by the National Institute of Environmental Health Sciences (NIEHS, 1998) to evaluate the health effects from exposure to ELF. The Working Group concluded that ELF fields are a *possible human carcinogen*. The evidence in support this decision resulted from studies on childhood leukemia in residential environments and on chronic lymphocytic leukaemia (CLL) in adults in occupational settings. "The fact that limited evidence was seen for CLL in adults should not be construed as providing support for the finding with regard to leukemia in children. Childhood leukemia and adult CLL are very different diseases with different etiologies. Also, the inadequacy of the evidence for an effect on the risk for CLL in adults in the studies of residential exposure neither supports nor refutes the findings in the studies of occupational exposure. The *in vitro* and mechanistic data provide, at best, marginal support for the conclusion that ELF fields are possibly carcinogenic to humans. While ELF magnetic fields at intensities greater than 100 μT provide moderate support for effects *in vitro*, there was little evidence of effects at intensities below this limit, which cover most of the range of exposure in the studies of residential childhood exposure and adult occupational exposure. Relatively few of the studies of occupational exposure addressed exposure to electric fields. Finally, the inadequate evidence from long term bioassays for carcinogenicity in rodents is driven more by lingering concerns about single findings in two separate studies than by an overall concern that something has been missed in these studies or that there is a trend toward a positive effect in poorly conducted studies."

Pooled analyses (Ahlbom et al, 2000; Greenland et al 2000) of the epidemiological studies on exposure to ELF magnetic fields suggest that residence in homes near external power lines is associated with an approximate 1.5~2.0 fold relative risk of childhood leukaemia. These data were influential for a working group of the International Agency for Research on Cancer (IARC) concluding that ELF magnetic fields were a "possible human carcinogen" for childhood leukaemia. "Possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

This classification is the weakest of three categories ("is carcinogenic to humans", "probably carcinogenic to humans" and "possibly carcinogenic to humans") used by IARC to classify potential carcinogens based on published scientific evidence. Some examples of well known agents that have been classified by IARC are listed in the table.

ELF fields are known to interact with tissues by inducing electric fields and currents in them. This is the only established mechanism of action of these fields. However, the electric currents induced by ELF fields commonly found in our environment are normally much lower than the strongest electric currents naturally occurring in the body such as those that control the beating of the heart.

Since 1979 when epidemiological studies first raised a concern about exposures to power line frequency magnetic fields and childhood leukaemia, a large number of studies have been conducted to determine if measured ELF exposure can influence cancer development, especially in children.

Classification	Examples of Agents
Carcinogenic to humans (usually based on strong	Asbestos Mustard gas

evidence of carcinogenicity in humans)	Tobacco (smoked and smokeless) Gamma radiation
Probably carcinogenic to humans (usually based on strong evidence of carcinogenicity in animals)	Diesel engine exhaust Sun lamps UV radiation Formaldehyde
Possibly carcinogenic to humans (usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)	Coffee Styrene Gasoline engine exhaust Welding fumes ELF magnetic fields

There is no consistent evidence that exposure to ELF fields experienced in our living environment causes direct damage to biological molecules, including DNA. Since it seems unlikely that ELF fields could initiate cancer, a large number of investigations have been conducted to determine if ELF exposure can influence cancer promotion or co promotion. Results from animal studies conducted so far suggest that ELF fields do not promote cancer.

However, two recent pooled analyses of epidemiological studies provide insight into the epidemiological evidence that played a pivotal role in the IARC evaluation. These studies suggest that, in a population exposed to average magnetic fields in excess of 0.3 to 0.4 μT, twice as many children might develop leukaemia compared to a population with lower exposures. In spite of the large number data base, some uncertainty remains as to whether magnetic field exposure or some other factor(s) might have accounted for the increased leukaemia incidence.

These uncertainties occur for a number of reasons. Childhood leukaemia is a rare disease with 4 out of 100,000 children between the age of 0 to 14 diagnosed every year. Also average magnetic field exposures above 0.3 or 0.4 μT in residences are rare. Less than 1% of populations using 240 volt power supplies are exposed to these levels, although this may be higher in countries using 120 volt supplies.

Occupational studies have generally used job titles, sometimes in combination with workplace ELF field measurements, to determine if any association exists between exposure to these fields and cancer. Elevated risks of various cancers have been reported, especially leukaemia, nervous system tumours and breast cancer; but the lack of uniformity of the results has been a major concern. Any excess cancer risk among electrical workers, compared to other occupations, is small and difficult to detect using epidemiological methods. Studies so far have been complicated by the lack of adequate exposure assessment in the workplace and possible confounding factors.

The basic problem with all epidemiological studies so far has been the lack of any concept of dose or an exposure metric established from laboratory studies. Metrics used have generally been cumulative exposure or time-weighted average field strength. Very little information has been obtained about exposure from appliances, ground currents or devices that may be associated with transient fields. Brief exposures to high amplitude magnetic field transients or to high frequency harmonics have not been assessed in published studies. Personal dosimeters do not exist that can capture this information.

■ ELF Research needs

Independent replication of some key studies is a high priority. When effects are robust, replication should be straightforward and can be used as a basis for extending observations. It is important to characterize the dose-response relationship (field strength, threshold and exposure duration) of any effect, particularly at environmentally relevant field strengths.

Where possible, *in vivo* studies should consider exposures that include intermittency, transients, and duration as important variables. In addition, it would be valuable to consider the interactions of ELF fields with other agents, such as ionizing radiation and chemicals. These interactions should test the hypothesis that ELF fields may act as a co promoter for cancer, but other end points suggested by the *in vitro* literature should also be examined. Wherever possible, exposures should be relevant to those experienced by humans in occupational and residential settings. Some cancer related studies using various animal models are currently under way. Research gaps for which additional results are needed, are as follows:

1. Confirmation and extension of animal studies reporting increased tumour incidence when magnetic fields are applied in combination with chemical carcinogens. These experiments should focus on dose-response relationships and the relationship between different exposure conditions.
2. Confirmation and extension of studies suggesting that magnetic field exposure influences mammary cancer development. Possible changes in relevant hormonal factors in magnetic field-exposed animals and controls should be investigated to examine potential mechanisms.
3. Neurophysiology neurobehavioural studies using models of neurodegenerative diseases are indicated because of recent reports of possible ELF field influence on human neurodegenerative diseases, such as Alzheimer disease.
4. While most studies of ELF field effects on various end points in reproduction and development have been negative, new studies should provide information on long-term neurobehavioural consequences following *in utero* exposure to magnetic fields. These studies should address whether ELF fields can produce effects on early

brain development as measured in functional behaviour in adult animals.

ELF epidemiology research needs

The most important prerequisite for future epidemiological studies is a clearer understanding of what metric should be used to characterize ELF field exposure. This may come from laboratory work or from additional hypothesis-generating epidemiological studies, each of which has advantages and disadvantages in cost, time, and precision. Project designs for new epidemiological research should, within the limits of what is possible, increase the role of measured past and present exposures. Dependence on surrogates, such as wire codes and job classifications, should decrease, particularly if data do not exist that establish how well the surrogates select for historical exposure. The *a priori* estimates of the power of future studies must be strong enough to predict useful information, given the outcomes of past research.

Because many, but not all studies show a small but significant excess in childhood leukaemia associated with residence in high wire code homes in the US (the only country where this surrogate has been used) a concerted effort is needed to explain this association. While efforts have been made to define the relationship between wire codes and average magnetic field exposure or socio-economic confounding factors, little evidence is available about the relationship between wire codes and high amplitude transient fields or high frequency harmonics. Future studies should include these and ground currents in the exposure assessments. Another aspect to be seriously pursued in future studies is the inclusion of non occupational exposure.

With the above caveats, needed future epidemiological studies include:

1. Studies of the relationship between exposure and cancer incidence that properly assess both residential and occupational exposure over long periods, including transient magnetic field exposure and high-frequency harmonics.
2. Studies to determine if correlates of wire codes, such as traffic density, age of home and sociodemographic characteristics of home occupants, can explain the statistical relationship between wire codes and childhood leukaemia.
3. Studies of the relationship between breast cancer and field exposure, including evaluation of both average field levels and of transients and high frequency components and taking into account both occupational and non-occupational exposures.
4. Studies of the relationship between neurodegenerative disorders and field exposure, including evaluation of the role of average fields levels, transients and high-frequency components. Both occupational and non occupational exposures should be considered.
5. Studies of the relationship between heart disease end points and exposure to ELF fields, including evaluation of the role of transient and high frequency components and taking into account both occupational and non-occupational exposures.

Volunteer studies

Further studies are needed, especially using transient and high frequency components typical of environmental ELF fields, to determine:

1. Whether any component of the human melatonin hormone system is susceptible to ELF field exposure and, if so, the likely health consequence of this susceptibility.
2. Whether sleep disruption, changes in neurotransmitter metabolism, and learning and memory are associated with ELF field exposure.
3. The relationship between field exposure and slowing and variability in heart rate.
4. Whether electrophysiological indices of central nervous system activity and function are affected by ELF fields.

Subjective effects

Given the limited evidence, but widespread concern about subjective effects, more research is needed to determine:

1. Whether these health effects can be substantiated and can be related to EMF exposure.
2. Why people experiencing apparent hypersensitivity and attributing it to EMF exposure, cannot determine reliably whether the fields are on or off in laboratory tests. The current laboratory results should be extended, and their relevance clarified.

■ Intermediate frequencies (IF)

Compared to the extremely low frequency (ELF) and radiofrequency (RF) range, few biological effects studies have been conducted and few reviews have been published that focus on health risks. International EMF exposure guidelines (ICNIRP, 1998) at IFs have been established by extrapolating limits from the ELF and RF frequency ranges, based on principles of coupling of external fields with the body and assumptions about the frequency dependence of bioeffects. Because applications of EMF in this frequency range are increasing rapidly, it is important to properly evaluate the significance of any effects on human health.

A wide range of equipment produces electric or magnetic fields in the IF range. In most cases the exposures to humans from these devices are within recommended limits, although the guidelines may be exceeded in some cases. Workers in a few occupational groups (operators of heat sealers and induction heaters, some military personnel, technicians working near high

powered broadcast equipment) are undoubtedly exposed to considerably higher levels of IF fields than the general population.

Mechanisms of Interaction

Understanding the mechanisms of interaction between EMF and biological systems is important for several reasons. First, determining the thresholds for hazard at IFs currently requires extrapolation of biological data from lower and higher frequency ranges, which requires assumptions about the frequency dependence of the effect. For this, an understanding of the mechanisms for effects is important. More generally, hypotheses about mechanisms of interaction can help to clarify biological phenomena and guide further experimentation.

Several mechanisms, both thermal and nonthermal, by which electromagnetic (primarily, electric) fields can interact with biological systems are well established. Each mechanism is characterised by a strength of interaction and a response time. The first determines the threshold for producing observable effects in the presence of random thermal agitation (noise). The second determines the frequency response of the effect, which is typically characterised by a cut off frequency (above which the threshold increases with frequency). In addition, EMF can heat tissue, resulting in a variety of thermal effects. The limiting hazard will arise from the adverse effect (thermal or nonthermal) that has the lowest threshold under given exposure conditions.

■ IF biological and health effects

Most biological effects studies in the IF range have employed field levels far above exposure guidelines, and above realistic exposure levels for humans. However, in some cases the exposure levels have been below recommended limits. Virtually none of the effects described below have any apparent explanation in terms of accepted biophysical mechanisms of interaction. The results and conclusions here are from the recent review by Litvak et al (in press)

Most studies have used field levels above international guidelines for human exposure or otherwise have unclear significance to health risk. As with other EMF ranges, few reported effects of IF fields have been subject to independent confirmation, and in some cases investigators have suggested the presence of confounding effects that may have led to previously reported effects of IF. Most epidemiological studies on human exposure to IFs concern possible reproductive effects and were motivated by health concerns from exposure to fields emitted by VDUs. Other studies have been reported on workers occupationally exposed to fields in the IF range. However, because of the weak associations in these studies, the use of multiple comparisons in the data analysis, and other uncertainties, they provide no strong evidence for health hazards.

The working group formed during the WHO meeting on the IF, held in Maastricht in June 1999, felt that the health implications of these findings are difficult to assess. A detailed review of the IF range is shortly to be published in Bioelectromagnetics (Litvak et al., in press). The general consensus of the working groups was that current scientific evidence does not show the presence of health hazards from IFs at exposures below recommended guidelines. However, the biological data is sparse, particularly related to effects of low level exposure. A few epidemiology studies have suggested links between IF exposure and health effects, but they are compromised by technical problems and cannot be reliably interpreted. Even for established hazards, there is a need to better determine thresholds, particularly for fields with complex waveform or pulsed fields. Any epidemiological studies at IFs should be preceded by pilot studies demonstrating their feasibility.

■ Radiofrequency Fields

Common sources of RF fields include: monitors and video display units (3 - 30 kHz), AM radio (30 kHz - 3 MHz), industrial induction heaters (0.3 - 3 MHz), RF heat sealers, medical diathermy (3 - 30 MHz), FM radio (30 - 300 MHz), mobile telephones, television broadcast, microwave ovens, medical diathermy (0.3 - 3 GHz), radar, satellite links, microwave communications (3 - 30 GHz) and the sun (3 - 300 GHz).

Hazards of exposure to high levels of RF fields, which result in tissue heating, are basically understood, although there are still a number of unresolved issues. Thermal hazards are associated with acute exposures and are thought to be characterized by thresholds, below which they are not present. However, many studies have suggested that RF exposure at low levels may have biological effects, but they have either not been consistently replicated or else their significance for human health cannot be adequately assessed using information currently available. Scientific research into possible health effects has been unable to keep pace with the rapid advances in the applications of RF fields in our working and living environment. This delay has led to widespread concerns among the general public and workforce that there are unresolved health issues that need to be addressed as a matter of urgency.

Although many reports in the scientific literature claim effects in biological systems exposed to low levels of RF, of principal concern is to determine if these exposures produce any adverse health effects. In this respect, one of the major challenges is to better understand or establish the effects reported at low RF levels. Are there mechanisms by which hazards to humans at these low exposure levels might be produced?

Mechanisms of interaction

RF fields induce torques on molecules, which can result in displacement of ions from unperturbed positions, vibrations in bound charges (both electrons and ions), and rotation and reorientation of dipolar molecules such as water. These mechanisms, which can be described by classical electrodynamic theory, are not

capable of producing observable effects from exposure to low level RF fields, because they are overwhelmed by random thermal agitation. Moreover, the response time of the system must be fast enough to allow it to respond within the time period of the interaction. Both considerations imply that there should be a threshold (below which no observable response occurs) and a cut off frequency (above which no response is observed). These thresholds would be expected to be present even in more refined models if they correctly take into account thermal noise and the kinetics of the system.

Exposure to electromagnetic fields at frequencies above about 100 kHz can lead to significant absorption of energy and temperature increases. In general, exposure to a uniform (plane wave) electromagnetic field results in a highly non uniform deposition and distribution of energy within the body, which must be assessed by dosimetric measurement and calculation. For absorption of energy by the human body, electromagnetic fields can be divided into four ranges:

- frequencies from about 100 kHz to less than about 20 MHz, where absorption in the trunk decreases rapidly with decreasing frequency, and significant absorption may occur in the neck and legs;
- frequencies in the range from about 20 MHz to 300 MHz, at which relatively high absorption can occur in the whole body, and to even higher values if partial body (e.g., head) resonances are considered;
- frequencies in the range from about 300 MHz to several GHz, at which significant local, non-uniform absorption occurs;
- frequencies above about 10 GHz, at which energy absorption occurs primarily at the body surface.

In tissue, SAR is proportional to the square of the internal electric field strength. Average SAR and SAR distribution can be computed or estimated from laboratory measurements. Values of SAR depend on the following factors:

- the incident field parameters, i.e. the frequency, intensity, polarization, and source object configuration (near field or far field);
- the characteristics of the exposed body, i.e. its size, internal and external geometry, and the dielectric properties of the various tissues;
- reflection, absorption and scattering effects associated with the ground or other objects in the field near the exposed body.

When the long axis of the human body is parallel to the electric field vector, and under plane wave exposure conditions (i.e. far field exposure), whole body SAR reaches maximal values. The amount of energy absorbed depends on a number of factors, including the size of the exposed body. "Standard Reference Man", if not grounded, has a resonant absorption frequency close to 70 MHz. For taller individuals the resonant absorption frequency is somewhat lower, and for shorter adults, children, babies, and seated individuals it may exceed 100 MHz. The values of electric field reference levels are based on the frequency-dependence of human absorption. In grounded individuals, resonant frequencies are lower by a factor of about 2 (ICNIRP, 1998).

■ RF biological effects

In Vitro

Reports from *in vitro* research indicate that low level RF fields may alter membrane structural and functional properties that trigger cellular responses. It has been hypothesized that the cell membrane may be susceptible to low level RF fields, especially when these fields are amplitude-modulated at ELF frequencies. At high frequencies, however, low level RF fields do not induce appreciable membrane potentials. They can penetrate the cell membrane and possibly influence cytoplasmic structure and function. These RF field induced alterations, if they occur, could be anticipated to cause a wide variety of physiological changes in living cells that are only poorly understood at the present time.

A lack of effects of RF exposure on mutation frequency has been reported in a number of test samples including yeast and mouse lymphoid cells. No effect of RF field exposure on chromosome aberration frequency in human cells has been confirmed.

Animal studies

In contrast to the evidence given above, several rodent studies indicate that RF fields may affect DNA directly. These papers report quantitative data subject to sources of inter-trial variation and experimental error such as incomplete DNA digestion or unusually high levels of background DNA fragmentation. These experiments need to be replicated before the results can be used in any health-risk assessment, especially given the weight of evidence that RF fields are not genotoxic. Further, in animal studies, most well conducted investigations report a lack of clastogenic effect in the somatic or germ cells of exposed animals (ICNIRP, 1998). Other investigations that require further attention relate to possible synergistic action of RF exposures with chemical or physical mutagens or carcinogens.

Most cancer studies of animals have sought evidence of changes in spontaneous or natural cancer rates, enhancement by known carcinogens, or alterations in growth of implanted tumours (ICNIRP, 1998). However, they have provided only equivocal evidence for changes in tumour incidence. Chronic RF field exposure of mice at 2-8 W/kg resulted in an SAR dependent increase in the progression or development of spontaneous mammary or chemically induced skin tumours. In a further study, exposure at 4-5 W/kg, followed by application of a sub carcinogenic dose of a chemical carcinogen to the skin, a procedure repeated daily, eventually resulted in a three fold increase in skin

tumours. However, at these high exposures, temperature-mediated effects cannot be excluded.

Studies in which cancer cells were injected into animals have reported a lack of effect of exposure to CW and pulsed RF fields on tumour progression. Progression of melanoma in mice was unaffected by daily exposure to pulsed or CW RF fields following subcutaneous implantation, and progression of brain tumours in rats was not affected by CW or pulsed RF fields following the injection of tumour cells into the brain.

Moderately lymphoma-prone Eµ-*Pim1* oncogene-transgenic mice were exposed or sham-exposed to radiofrequency fields for 1 h/day for up to 18 months using pulse modulations similar to that used for digital mobile telephones. Exposure was associated with a statistically significant, 2.4-fold increase in the risk of developing lymphoma (Repacholi *et al.* 1997). This long-term study needs replication and extension to other exposure levels and animal models before it can be used for health-risk assessments. Further research is also needed to determine the significance of effects in this transgenic model for human health risk.

Although weak evidence exists, it fails to support an effect of RF exposure on mutagenesis or cancer initiation. There is scant evidence for a co-carcinogenic effect or an effect on tumour promotion or progression. However, only a few studies have been published and these are sufficiently indicative of an effect on carcinogenesis to merit further investigation.

Effects on other systems

Early signs of neurotoxicity are often behavioural rather than anatomical. While many studies have been conducted at high-levels of RF exposure few relevant studies have used low-levels. Some of the more important studies are described below. The blood-brain barrier (BBB) is a specialised neurovascular complex that functions as a differential filter permitting selective passage of material from the blood into the brain. It maintains the physiological environment of the brain within certain limits that are essential for life. Although extensive previous research has been unable to reliably identify permeability changes at low levels of RF exposure, in recent studies, increased BBB permeability was reported for RF exposures at SARs as low as 0.016 W/kg. These studies need replication and extension to allow a better determination of any possible health consequence.

Exposure to very low levels of amplitude modulated RF fields were reported to alter electrical activity in the brain of cats and rabbits. These experiments need replication and extension.

Pulsed radiation

Exposure to low-level pulsed and CW RF fields has been reported to affect brain neurochemistry in a manner consistent with responses to stress. Effects on behaviour and drug interaction have been obtained with the same exposure parameters. Replication studies are needed to establish and provide further information on these effects.

Exposure to very intense pulsed RF fields suppresses the startle response and evokes body movements in conscious mice (ICNIRP, 1998). The mechanism for these effects is not well established, and is clearly associated with heating at higher absorbed energies.

People having normal hearing perceive pulse-modulated RF fields with carrier frequencies between about 200 MHz and 6.5 GHz; the so-called *microwave hearing* effect. The sound has been variously described as a buzzing, clicking, hissing or popping sound, depending on modulation characteristics. Prolonged or repeated exposure may be stressful.

Exposure to low levels of pulsed or CW RF fields may affect neurotransmitter metabolism and the concentration of receptors involved in stress and anxiety responses in different parts of the brain.

The retina, iris and corneal endothelium of the primate eye were reported to be susceptible to low-level RF fields, particularly when pulsed. Various degenerative changes in light sensitive cells in the retina, were reported at specific energies per pulse (10-µs pulses at 100 pps), as low as 2.6 mJ/kg after the application of a drug used in glaucoma treatment. However, these results could not be replicated for CW fields. Further replication studies are needed.

Epidemiological and human volunteer studies

Cancer: By far the greatest public concern has been that exposure to low-level RF fields may cause cancer. Of the epidemiological studies addressing possible links between RF exposure and excess risk of cancer, some positive findings were reported for leukaemia and brain tumours. Overall, the results are inconclusive and do not support the hypothesis that exposure to RF fields causes or influences cancer.

Review groups that evaluated possible links between RF exposure and excess risk of cancer have concluded that there is no consistent evidence of a carcinogenic hazard. In some studies there are significant difficulties in assessing disease incidence with respect to RF exposure and with potential confounding factors such as ELF and chemical exposure. Overall the epidemiological studies suffer from inadequate assessment of exposure and confounding, and poor methodology. Further studies are underway to evaluate potential carcinogenic effects of chronic exposure to low-level RF fields and more are needed.

Other outcomes

Other health outcomes investigated following RF exposure, include headaches, general malaise, short-term memory loss, nausea, changes in EEG and other central nervous system functions, and sleep disturbances. There have also been anecdotal reports from several countries of subjective disorders such as headaches associated with the use of mobile telephones. Whether exposure to RF fields at very low-levels can cause such subjective

effects has not been substantiated from current evidence, but further research is indicated.

Individuals have claimed to be *hypersensitive* to electromagnetic fields. The most common symptoms are headaches, insomnia, tingling and rashes of the skin, difficulty in concentrating and dizziness. Given the limited evidence and widespread concerns that the above effects have provoked, more research is needed to determine if these health effects can be substantiated.

Adverse maternal health outcomes, particularly spontaneous abortions and haematological or chromosome changes, have been reported to occur in certain populations exposed to RF fields. Some of these changes have also been reported in users of video display units. Taken overall, the studies in this area have not substantiated these effects.

RF Field Research Needs

Since the EMF Research Agenda was first published by WHO in 1996, many national and international agencies have funded research that contributes substantially towards the studies needed to make better health risk assessments. Most of the in vivo and in vitro studies have now been completed or are underway. A major epidemiological study being conduction under IARC supervision to determine if there is a relationship between mobile telephone use and head or neck cancers has been funded and commenced.

By far the most important deficiency in the RF research underway is in the area of effects on human volunteers. There is still a basic need to studies on human volunteers under laboratory conditions to determine basic physiological responses to pulsed, non-thermal levels of RF similar to those emitted by mobile telephones. It is anticipated that following the recommendations of the Stewart report, a further $10 million will be devoted to this research, with emphasis on human laboratory studies.

Thus it is important that details of WHO's research needs are clearly know to provide guidance on studies that will provide necessary health risk information.

Human laboratory studies

By far the greatest need is for basic studies, using established batteries of tests to investigate:

- Psychological effects related to the use of mobile phones (blood pressure, brain and cognitive function (including memory or learning), any other effects likely to effect the CNS, reaction times, auditory evoked potentials, EEG, ECG, EKG etc (others)
- Studies to determine if human brain function is affected by different RF pulsing regimens (test to Hyland-Frölich hypothesis)
- Effects on children to determine if they are more sensitive to RF effects
- People who claim to show a greater sensitivity to RF fields; hypersensitivity reactions, sleep disturbance, other subjective effects.

There should be part of the research program that is devoted to standard test and part to the encouragement of innovative ideas that investigate RF effects on human CNS function.

Animal studies

- Need to address long-term memory and behavioural studies in animals (Lai) since this cannot be done effectively in humans.
- Follow-up study on cancer promotion using DMBA.

In vitro studies

As a lower priority, there is a need to conduct:

- In vitro investigation of ODC and cell signalling molecules. The ODC results need to be resolved, as well as the ongoing debate about calcium efflux.
- Hippocampal slice preparation (Wood et al, 2000) study showing transient changes in evoked and spontaneous activity should be investigated further
- More complete study of the possibility that pulsed RF fields can initiate gene expression.

■ Further Reading

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ICNIRP

International Commission on Non-Ionizing Radiation Protection

http://www.icnirp.de/

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■ Abstract

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent scientific organization responsible for providing guidance and advice on the health hazards of non-ionizing radiation exposure

ICNIRP is an independent group of experts established to evaluate the state of knowledge about the effects of NIR on human health and well being, and, where appropriate, to provide scientifically based advice (guidelines) on limiting exposure. For other methods of protection against suspected harmful effects of NIR, the evaluation of literature by ICNIRP may serve as a valuable input. ICNIRP succeeded the International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) in 1992 and still retains a close association with the latter.

ICNIRP, as an international scientific advisory body, does not address social, economic or political issues. Membership of ICNIRP is limited to experts who are not affiliated with commercial or industrial enterprises. Thus, ICNIRP is free of vested commercial interest.

ICNIRP is the formally recognised non-governmental organisation in NIR protection for the World Health Organization (WHO), the International Labour Organization (ILO) and the European Union (EU). It maintains a close liaison and working relationship with other scientific bodies. These include the International Electrotechnical Commission (IEC), the European Committee on Electrotechnical Standardisation (CENELEC), the European COST Action, the International Commission on Illumination (CIE), the American Conference of Governmental and Industrial Hygienists (ACGIH), the International Standards Organization (ISO), the International Commission on Occupational Health (ICOH), the Institute of Electrical and Electronic Engineers (IEEE) and the US National Council for Radiation Protection and Measurement (NCRP). ICNIRP also enters into consultation with IRPA national radiation protection societies.

ICNIRP continuously monitors and periodically carries out critical reviews of the scientific literature concerned with the physical characteristics of NIR, sources and possible biological and adverse health effects. In doing so, ICNIRP limits its surveillance to published original scientific papers and reports that are generally available. ICNIRP performs such critical scientific analysis by evaluating the relevance, scientific quality and credibility of each report. To assist in this ongoing review process, ICNIRP has formed a number of scientific Standing Committees whose membership includes non-ICNIRP as well as ICNIRP experts. In addition, the Commission may appoint further experts as consulting members. ICNIRP can be seen as a repository of information on the epidemiological, medical, biological, physical and technological aspects of NIR.

In pursuit of its objectives, ICNIRP formulates guidelines on limiting exposure, and contributes scientific advice to environmental health criteria documents (published by WHO). ICNIRP also disseminates information on specific topics of importance to NIR protection by means of statements, practical occupational exposure guides (in collaboration with ILO) and scientific symposia proceedings.

ICNIRP recognises that the acceptability and adoption of a complete system of protection also requires data and evaluations based on social, economic and political considerations. It is ICNIRP's view that these matters are the responsibility of national governments and their authorities. ICNIRP and other scientific advisory bodies may, however, provide background information of importance to carrying out such evaluations.

Whereas ICNIRP provides general practical information on measurable levels that are derived from basic restrictions on exposure, it recognises the need for further technical advice on special exposure situations. This requires physics and engineering expertise to develop practical measures to assess and/or to enable assessment of compliance with ICNIRP exposure guidelines. This includes guidance on the principles and practice of measurements, design of equipment and/or shielding to reduce exposure, and, where appropriate, setting emission limits for specific types of devices. ICNIRP considers that the organisations best qualified to carry out such tasks are the international, regional and national technical standards bodies, including IEC, ISO, CIE, and CENELEC.

Different levels of an exposure may cause effects that differ in terms of consequences for the individual. Such information may be valuable for a national authority developing guidance or legal restrictions. In general, this

information would be made available in the scientific background documents provided by ICNIRP and WHO.

■ Main Commission

The Main Commission consists of a Chairman, Vice-Chairman and 12 members. Commission members are individual experts representing neither their countries nor their institution.

The duties of the Main Commission include

- Formulating and implementing the policy of the Commission in accordance with the Commission's Charter and resources available.
- Specifying, prioritising and directing the Commission's work programme.
- Providing Chairmanship and scientific expertise to the Standing Committees and coordinating their activities according to the needs of the Commission.
- Reviewing and approving proposed Commission publications.
- Fostering cooperation with other partner organizations in the field of non-ionizing radiation protection.

Commission Membership

Dr. A.F. McKinlay	Chairman, UK
Prof. Dr. J.H. Bernhardt	Vice Chairman , Germany
Prof. Dr. A. Ahlbom	Sweden
Dr. U. Bergqvist	Sweden
Dr. J.P. Césarini	France
Dr. F. R. De Gruijl	The Netherlands
Dr. M. Hietanen	Finland
Dr. R. Owen	USA
Dr. D.H. Sliney	USA
Prof. A. Swerdlow	UK
Prof. Dr. M. Taki	Chairman SC III Japan
Dr. T.S. Tenforde	USA
Dr. P. Vecchia	Italy
Dr. B. Veyret	France
Dr. M.H. Repacholi	Chairman Emeritus CH
Dipl.-Ing. R. Matthes	Scientific Secretary, Germany

■ Standing Committees

ICNIRP currently has four scientific Standing Committees: Epidemiology, Biology, Physics, and Optical Radiation. Each of these Standing Committees comprises internationally recognized experts in the area of study in question. Each is chaired by a member of the ICNIRP Main Commission and will usually contain one other Main Commission member. The size of the Standing Committees is usually limited to around seven experts.The duties of the Standing Committees include:

- Reviewing the scientific literature specific to the field of interest of each Standing Committee.
- Preparing specific reports and other publications requested by the Main Commission.
- Advising on the prepartion of exposure guidelines and other ICNIRP documents requiring multi-disciplinary input.
- Providing expert advice through ICNIRP-organized scientific seminars and other scientific meetings.

The working programme of the Standing Committees include:

- Establish the committee.
- Assign the task of creating and maintaining the data Develop a format and an organization for the consecutive reviewing of the new literature.
- Develop a strategy for already existing publications.
- Plan meetings in co-ordination with ICNIRP and collaborating projects.

■ Consulting Members

ICNIRP constantly seeks to extend and improve its knowledge base in order to ensure that it continues to provide sound science-based advice on non-ionizing radiation protection. This task has become increasingly complex and demanding, particularly with the rapid expansion of new technologies employing electromagnetic fields, radiofrequency radiation and optical devices that could result in an increase in the exposure of people. ICNIRP recognises the need to benefit from as wide a range of professional expertise and scientific/technical knowledge as possible and, to achieve this, has invited a number of key experts in specific areas in the role of "Consulting Members".

Consulting members are invited to help ICNIRP through the work programme of each Standing Committee. They bring to ICNIRP specific expertise, often in a specific and highly technical area, and required for a specific task in hand. They also provide a broadening of the scientific consultation that ICNIRP employs to review its publications.

The Secretariat provides scientific administrative support to ICNIRP and acts as the main point of contact and the principal channel for ICNIRP and its members. It also provides organizational support for all ICNIRP meetings and workshops.

■ Scientific Secretary

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Deputy Secretary Dipl.-Verw. K. Chabrel
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ICNIRP's Publications

ICNIRP endeavours to communicate its views, advice and recommendations as widely as possible and to consult on these with radiation protection and other medical and science professionals world-wide.

Certain ICNIRP publications can be downloaded from the ICNIRP site. ICNIRP books can be ordered at the following address: SMI (Distribution Services) Limited P.O. Box 119 Stevenage, Hertfordshire SG1 4TP UK, www.earthprint.com

ICNIRP's publications broadly consist of::

Reviews of the published scientific literature. These set out the science base and provide ICNIRP's interpretations of the results of the science in respect of understanding effects on human health. In the past such reviews were published in the WHO Health Criteria Documents Series. They are now published as ICNIRP stand-alone publications.

Exposure Guidelines. These are based on reviews of the science, they summarise scientific results and set out the basis for limiting exposure and recommend exposure limits. ICNIRP Exposure Guidelines are published in the Journal "Health Physics".

Statements. These provide information and advice on specific topics of non-ionizing radiation protection and/or radiation protection issues related to specific devices or exposure situations. ICNIRP Statements are also published in "Health Physics".

Occupational Practical Guides. These are produced by ICNIRP and address specific topics on occupational exposure to non-ionizing radiation. They are published by the International Labour Office in its "Occupational Safety and Health Series".

General Documents. These are documents setting out general policy issues such as the basis for exposure guidelines and reviews of the science. These may also be published in Health Physics or as separate ICNIRP publications.

Proceedings. These are publications resulting from scientific seminars, workshops and conferences organised by ICNIRP and/or its partner organizations in non-ionizing radiation protection. Proceedings are published either in special editions of scientific journals or as separate ICNIRP publications.

Hitherto, ICNIRP exposure guidelines and statements have been reviewed through the members of the world-wide network of national IRPA-affiliated radiation protection societies. This process calls on all reviews to be completed within a period of 90 days. Recently ICNIRP has extended this review process to include ICNIRP's International Partners in Non-Ionizing Radiation Protection. All comments received from such reviews are considered by ICNIRP in producing final publications.

Work plan[1]

ICNIRP Documents

General System of Protection against NIR

This document sets out the basis for ICNIRP's approach to non-ionizing radiation protection. It has been subject to external review and comments and has been approved by the Commission for publication. It has been accpeted in "Health Physics".

ICNIRP Guidelines on Exposure Limits

- *Ultraviolet Radiation*

The need for revision of guidelines on limiting exposure to ultraviolet radiation is under consideration by the Commission.

- *Airborne Ultrasound*

The need for revision of guidelines on limiting exposure to airborne ultrasound is under consideration by the Commission.

ICNIRP Statements

- *Magnetic Resonance Imaging (MRI)*

The Commission is reviewing the need for further advice on MRI. A workshop was held in France in October 2001.

- *Pulsed Magnetic Fields*

A Statement on pulsed magnetic fields has been approved by the Commission for formal review and comment.

- *UVR Sunbeds*

A draft statement has been produced and has been subject to the formal review and comment process. The Commission is completing the final version of the Statement.

- *Medical Ultrasound*

The Commission is reviewing the need for further advice on medical ultrasound.

ICNIRP Scientific Reviews

- *Review of Epidemiology relating to exposure to Static and ELF (0-100 kHz) fields*

This review has been completed by Standing Committee I (Epidemiology) under the Chairmanship of Professor Anders Ahlbom. The Review has been approved by the Commission and has been accepted for publication (later in 2001) in a scientific journal.

- *Review of Biological studies relating to exposure to Static and ELF (0-100 kHz) fields*

This review is at an advanced draft stage and will be completed by Standing Committee II (Biology) under the Chairmanship of Professor Bernard Veyret. It will be published by ICNIRP during 2001.

- *Review of Physical and Engineering relating to exposure to Static and ELF (0-100 kHz) fields*

This review is at an advanced draft stage and will be completed by Standing Committee III (Physics and Engineering) under the Chairmanship of Professor Masao Taki. It will be published by ICNIRP during 2001.

[1] Last updated, July 2001

- *Review of Epidemiology relating to exposure to RF Radiation (100 kHz-300GHz)*

This review will commence during 2002 and will be undertaken by Standing Committee I (Epidemiology) under the Chairmanship of Professor Anders Ahlbom.

- *Review of Biological studies relating to exposure to RF Radiation (100 kHz-300GHz)*

This review will commence during 2002 and will be undertaken by Standing Committee II (Biology) under the Chairmanship of Professor Bernard Veyret.

- *Review of Physical and Engineering relating to exposure to RF Radiation (100 kHz-300GHz)*

This review will commence during 2002 and will be undertaken by Standing Committee III (Physics and Engineering) under the Chairmanship of Professor Masao Taki.

- *Review relating to exposure to Laser and Optical Radiation*

This review has commenced and is being undertaken by Standing Committee IV (Optical Radiation) under the Chairmanship of Dr David Sliney.

Practical Guides for Protection of Workers

- *UV Protection for Workers*

Drafting of this document is underway. It is intended for publication by the International Labour Office (ILO) and is being undertaken by Standing Committee IV (Optical Radiation) under the Chairmanship of Dr David Sliney.

Symposia and Workshops - International Seminars

- *UV-Index*

This meeting took place in December 2000 in Munich, Germany. The resulting material is being compiled for publication by WHO.

- *Fifth International Non-Ionizing Radiation Workshop*

This Workshop will be held at a venue in Spain following the IRPA Congress in 2004.

- *EC 5th Framework Concerted Action on the Health Impact from the use of Electronic Article Surveillance Systems, RF Identification Devices and Metal Detectors*

This Action is led by Professor Juergen Bernhardt. Several meetings have been held and a report is being prepared by ICNIRP to be sent to the European Commission by the end of 2001.

IEEE EMF HEALTH & SAFETY STANDARDS

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■ ABSTRACT

With roots dating back to 1884, the Institute of Electrical and Electronics Engineers (IEEE) is the world's largest technical professional society, with more than 325,000 members, 1/3 from outside the United States. The development of internationally recognized voluntary standards, through an open consensus process, has long been a major effort of the IEEE. In 1966, IEEE co-sponsored the first US radio frequency (RF) standard (C95.1-1966). In 1982, C95.1-1982 was the first national standard in which field limits were derived from the frequency-dependent dosimetric quantity "specific absorption rate" (SAR). Dosimetry and a threshold SAR of 4 W/kg are now the bases for most of the world's RF safety standards and guidelines, including those of National Radiological Protection Board (NRPB), International Commission on Non-Ionizing Radiation Protection (ICNIRP), North Atlantic Treaty Organization (NATO), and the United States Department of Defense.

■ INTRODUCTION

The IEEE is one of the largest professional organizations and is composed of a number of professional societies (e.g., Engineering in Medicine and Biology Society; Microwave Theory and Techniques Society). Exposure standards pertaining to subjects that are of interest to more than one society (e.g., radio frequency safety standards) are developed by Standards Coordinating Committees (e.g., SCC-28, SCC-34) that are sponsored by the IEEE Standards Board. The history of the American National Standard Institute (ANSI)/IEEE RF/Microwave exposure standards is certainly impressive. There are several recent reviews of the ANSI/IEEE history and process [1-4]. In 1953, the 10-mW/cm^2 exposure standard was recommended to the United States Navy and this standard was based on simple thermal models. In 1959, the United States America Standards Institute (USASI) C95 project was chartered and sponsored by the United States Department of the Navy and IEEE. On November 9, 1966, the ANSI C95.1-1966 standard was approved and was based on simple thermal models. This standard covered 10 MHz to 100 GHz, the exposure limit was 10 mW/cm^2, and the 0.1-hour (6 minute) averaging time was introduced. Remarkably, the entire standard was only 1.2 pages in length and the cover page is shown below:

In 1971, the ANSI C95.1-1971 standard was approved and limits were established for E^2 and H^2. In 1982, ANSI C95.1-1982 was approved and this was the first national standard to incorporate dosimetry, was frequency dependent, and based on threshold SAR for behavioral disruption. The incorporation of limits based on SAR was critical since the incident and internal electromagnetic fields can be very different depending upon the size, shape, and composition of the object. As we know today, SAR is the common unit for comparing and extrapolating laboratory results from bioeffects studies.

In 1986, the National Council on Radiation Protection and Measurements (NCRP) published exposure recommendations that were SAR based, set occupational exposure limits the same as ANSI C95.1-1982, and set lower limits for the general public. In 1988, the C95 committee became the IEEE SCC-28. In 1991, the IEEE Standards Board approved the C95.1-1991 standard. This standard was two tiered, was based on SAR values, provided relaxation of limits for partial-body exposures, contained rules and definitions necessary for implementation, and was developed after an extensive evaluation of the scientific literature (see Attachment 1). During the literature assessment,

classifications of findings were made without prejudgement of the mechanisms of effects. The intent was to protect exposed humans from harm by *any* mechanism, including those from excessive elevation of body temperature. The Biological Validiation Working Groups were as follows: Behavior, Biorhythms, Cardiovasculature, Central Nervous System, Combined Effects, Development and Teratology, Endocrinology, Genetics, Hematology-Immunology, Metabolism and Thermoregulation, Modulation, Oncology, Physiology, and Visual Systems. The finding of these groups was that the most sensitive measures of potentially harmful biological effects were based on the disruption of food-motivated behavior in several animal species under wide-ranging field parameters (see Attachment 2).

The Maximum Permissible Exposure (MPE) values are based on limiting the SAR to:

	Controlled/ Occupational	**Uncontrolled/ General Public**
Whole-Body Average	0.4 W/kg	0.08 W/kg
Spatial Peak*	8.0 W/kg	1.6 W/kg

* Per gram of tissue in the shape of a cube

Controlled environments are locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons, or as the incidental result of transient passage through areas where analysis shows that the exposure levels may be above the MPEs for the uncontrolled environment, but do not exceed the MPEs for the controlled environment.

Uncontrolled environments are locations where there is exposure of individuals who have no knowledge or control of their exposure. The exposures may occur in living quarters or workplaces where there are no expectations that the exposure levels exceed the MPEs for the uncontrolled environment.

The exposure values (the values that are compared with the appropriate MPEs) in terms of electric and magnetic field strengths are the mean values obtained by spatially averaging the squares of the fields over an area equivalent to the vertical cross-section of the human body. The spatial averaging can be obtained by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human. An approximate method for spatial averaging is to make measurements at equal intervals (at least ten) along the axis of the projected area of the exposed subject. The spatial average is equal to the sum of the squares of the measured fields divided by the number of measurements.

Above 15 GHz, the averaging time decreases with increasing frequency from 6 and 30 minutes for the controlled and uncontrolled environments, respectively, to 10 seconds at 300 GHz. The 10 second averaging time at 300 GHz (1 mm wavelength) is consistent with the ANSI Z136.1-1993 (safe use of lasers) at 1 mm (where the two standards meet). The averaging time was reduced in the 1991 standard to preclude second degree (partial thickness) skin burns associated with short exposures at frequencies where the energy is absorbed in superficial tissues. For example, a 6-minute averaging time and a 5-mW/cm^2 MPE would allow exposure to a peak power density of 3.6 W/cm^2 for a 0.5 sec exposure (once every 6 minutes), which would be above the threshold for skin burn from a white light or infrared source.

Overall, the recommendations made in the IEEE C95.1-1991 standard are designed to prevent harmful effects in humans being exposed to electromagnetic fields in the frequency range of 3 kHz to 300 GHz. These exposure limits are biologically based and reflect a consensus interpretation of relevant studies from the bioelectromagnetics literature by qualified scientists, physicians, and engineers. Adjustments to the recommendations as a convenience to special interest groups are not part of the process.

In 1997, the literature evaluation began for the next revision of the exposure standard. This will be the most comprehensive literature evaluation ever take for a RF/microwave safety standard. Currently, there are approximately 1400 citations in the database (http://grouper.ieee.org/groups/scc28/).Peer-reviewed and non-peer-reviewed publications, book chapters, and reports are included in the database. Evaluations are being completed by topic (engineering, epidemiology, *in vivo, in vitro*, peripheral). Some of the issues to be addressed in revising the standard are: microwave/millimeter wave averaging time, the need for two tiers, and spatial-peak SAR values and averaging volume.

The IEEE SCC-28 is one of the several international organizations that develop safety criteria for RF/microwave exposure. For standards harmonization, it is important that members of these international organizations interact with one another to understand the rationale for exposure limits.

■ IEEE SCC PROCEDURES

IEEE Standards are developed through an open consensus process (see Attachment 3). Approval of an IEEE Standard (at the subcommittee level and at the main committee level) requires a balance of interests on committees, 75% return of ballots (including abstentions), approval of 75% of returned ballots (excluding abstentions), attempts to reconcile all negative ballots, circulation of unreconciled ballots to allow voters to reaffirm, comment, or change their vote, and coordination with other societies and organizations.

Currently in IEEE/ICES SCC-28, there are over 100 members from 13 countries. In recognition of the growing international membership of SCC-28, IEEE established the International Committee on Electromagnetic Safety (ICES) in March 2001 as an umbrella organization for SCC-28 and in the future for SCC-34 and any other SCC involved in developing standards for the safe use of electromagnetic energy. Members of the IEEE/ICES SCC-28 Executive Committee are: Chair: Dr. Eleanor Adair, Past Chair: Dr. John Osepchuk, Executive Secretary: Ronald Petersen, Treasurer: Arthur Varanelli, Membership: Dr. Tom McManus, and International Liaison: Dr. Michael Murphy.

The Executive Committee is responsible for policy, procedures, broad direction, and administration, as well as, adherence to process. The five subcommittees and Chairs are:

SC1: Techniques, Procedures, and Instrumentation; Howard I Bassen (hib@cdrh.fda.gov)

SC2: Terminology, Units of Measurements, and Hazard Communication; Richard A. Tell (rtell@radhaz.co)

SC3: Safety Levels with Respect to Human Exposures, 0 – 3 kHz; Kent C. Jaffa (kent.jaffa@pacificorp.com)

SC4: Safety levels with Respect to Human Exposures, 3 kHz – 300 GHz; Dr. C. K. Chou (ck.chou@motorola.com) and Dr. John A. D'Andrea (john.dandrea@navy.brooks.af.mil)

SC5: Safety Levels with Respect to Electro-Explosive Devices; John DeFrank (john.defrank@amedd.army.mil) and G. Drew Koban (gkoban@relay.nswc.navy.mil)

■ HOW TO JOIN SCC28

IEEE/ICES is an International Consensus Standard Setting Body. All are welcome to participate in the meetings and deliberations of SCC28 and to vote and participate fully on the Subcomittees. To apply for voting membership on SCC28, please send an e-mail or letter containing your resume to: Dr. Tom McManus, Membership Committee Chair, IEEE/ICES SCC28, Department of Public Enterprise, 44 Kildare Street, Dublin 2, Ireland (tommcmanus@dpe.ie).

■ INFORMATION ON IEEE SCC34

SCC34 develops performance standards for products using or producing electromagnetic energy. For further information, contact the Chair: Ronald C. Petersen (r.c.petersen@ieee.org).

■ REFERENCES

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[2] J.M. Osepchuk and R.C. Petersen. Safety Standards for Exposure to RF Electromagnetic Fields, *IEEE Microwave Magazine,* 2: 57-69, 2001

[3] R.C. Petersen, "New IEEE Standards on Measurement of Potentially Hazardous Radiofrequency/Microwave Electromagnetic Fields," in *Radiofrequency Radiation Standards – Biological Effects, Dosimetry, Epidemiology, and Public Health Policy,* B. Jon Klauenberg, M. Grandolfo, and D.N. Erwin, Eds., New York, Plenum Press, 1995, pp. 89-99.

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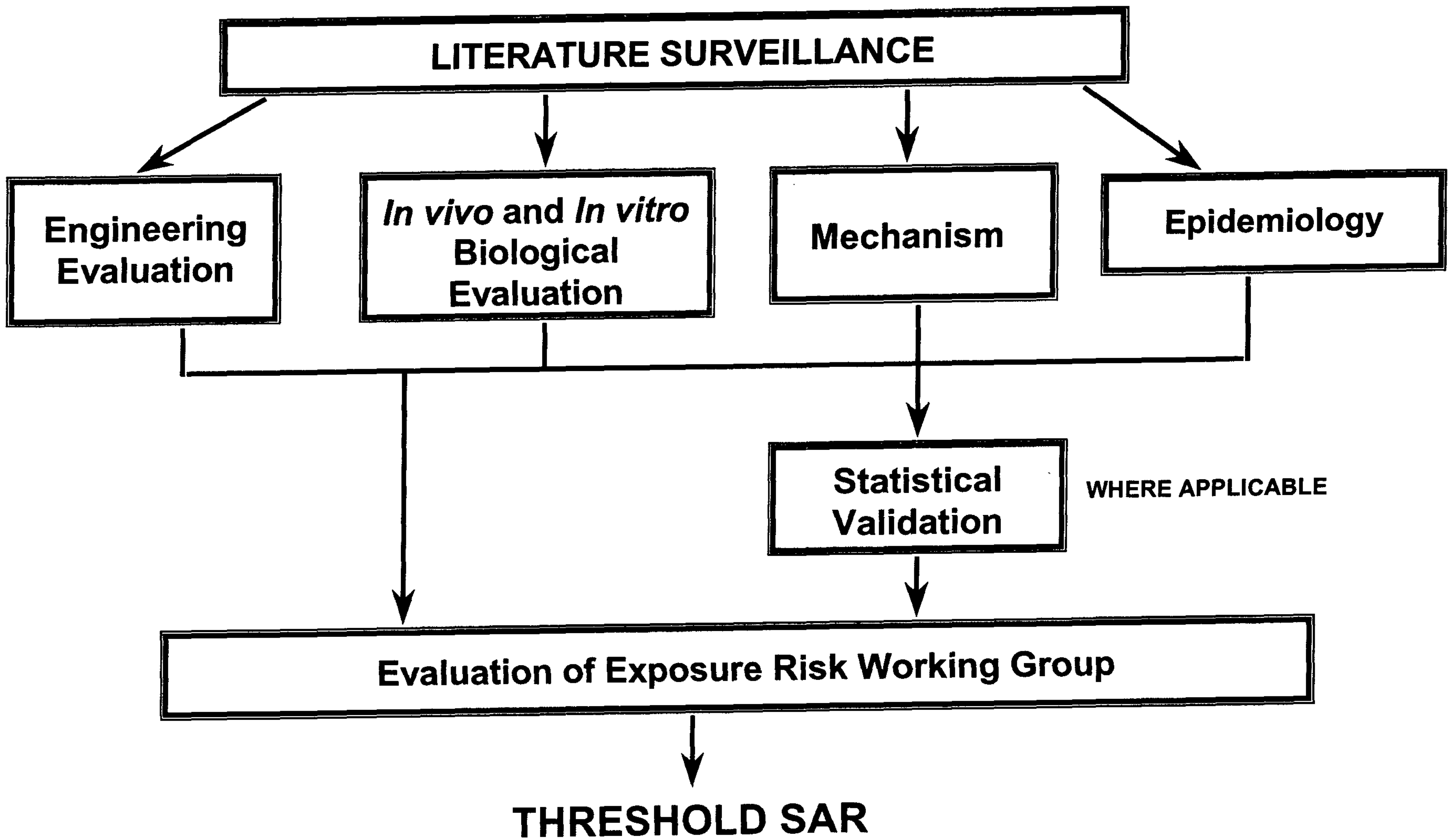
Attachment 1

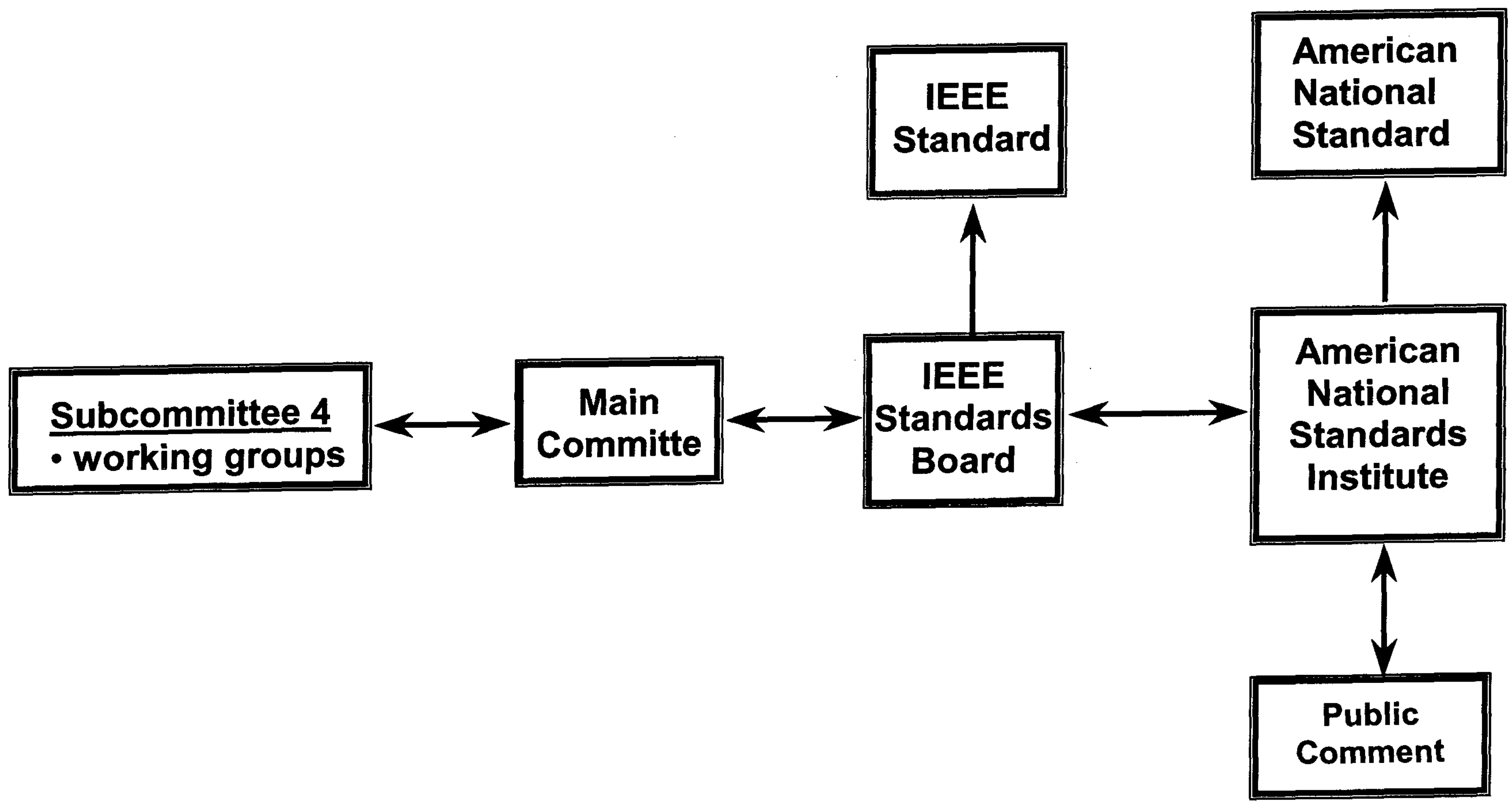


Attachment 2

Species and Conditions	CW 225 MHz	Pulsed 1.3 GHz	CW 2.45 GHz	Pulsed 5.8 GHz
Norwegian Rat				
Power Density:	-----	10 mW/cm^2	28 mW/cm^2	20 mW/cm^2
SAR:	-----	2.5 W/kg	5.0 W/kg	4.9 W/kg
Squirrel Monkey				
Power Density:	-----	-----	45 mW/cm^2	40 mW/cm^2
SAR:	-----	-----	4.5 W/kg	7.2 W/kg
Rhesus Monkey				
Power Density:	8 mW/cm^2	57 mW/cm^2	67 mW/cm^2	140 mW/cm^2
SAR:	3.2 W/kg	4.5 W/kg	4.7 W/kg	8.4 W/kg

Attachment 3

IEEE SCC-28 Standard-Setting Process



THE PRECAUTIONARY PRINCIPLE AND EMF

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■ Abstract –

The precautionary principle, a recommendation to consider action to avoid a possible harm even if it is not certain to occur, is variously defined and interpreted. I will present a range of definitions with an emphasis on their requirements for strength of evidence of harm and for actions to be taken. I will describe the variety of approaches that have been adopted in developing policy to address the issue of possible health effects of electric and magnetic fields (EMF) in the face of scientific uncertainty. Further, I discuss specific aspects of scientific uncertainty regarding EMF health risks particularly relevant to the development of precautionary principle policy. I will define and discuss prudent avoidance and other unique features of applications of the precautionary principle to EMF. I will conclude with examples from EMF policy decisions of risk tradeoffs that need to be considered in developing any precautionary principle policy, and provide recommendations for better ways to define and implement the precautionary principle.

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■ Introduction

The precautionary principle is one of many guides society can use when deciding whether to take action to protect people from possible harm. It is essentially a "better safe than sorry" approach suggesting that action should be taken to avoid harm even when it is not certain to occur.

All risks are to some degree uncertain, but the degree of uncertainty varies.

Clearly, when the harm associated with a risk is slight and its occurrence very uncertain, little or no action should be taken. Conversely, when the harm is great and there is little uncertainty about its occurrence, significant action is called for. It is in the gray area where substantial harm is postulated but certainty about whether it will occur is low, or where the degree of harm is low but the certainty is high, that policymaking is more difficult and some decision rules are needed as a guide to action. The precautionary principle provides a framework that can help provide a basis for decisions about whether to take action and what action to take in uncertain situations, if it is supplemented by other decision rules and risk evaluation.

■ Defining the Precautionary Principle

A wide variety of definitions and interpretations of the precautionary principle have been proposed. These definitions include three basic approaches:

1. *Where there are threats of serious or irreversible damage, uncertainty should not be a reason for postponing action to prevent that damage.*
2. *Where there are threats of serious or irreversible damage, precautionary measures should be taken even if cause-and-effect relationships are not clearly established.*
3. *Whenever an action or substance could cause irreparable/irreversible harm, even if that harm is not certain to occur, the action should be prevented and eliminated.*

Although each of the above definitions appears as a precautionary principle, important differences in the requirements for strength of evidence and actions to be taken make these approaches substantively different. Similarly, definitions of the precautionary principle imply a wide range of actions that should be taken once the strength of evidence requirement has been satisfied.

Another important difference in the various definitions of the precautionary principle lies in who bears the burden of proof. In some definitions, the burden of proof is shifted from the opponents of a possibly harmful action to its proponents (Wingspread, 1998). Finally, definitions of the precautionary principle reflect differing degrees of risk aversion.

On 2 February 2000, the European Commission approved an important communication on the Precautionary Principle providing guidelines for the application of the Principle. According to this communication, measures based on the precautionary principle should be

- tailored to the chosen level of protection,
- non-discriminatory in their application, i.e. they should treat comparable situations in a similar way,
- consistent with similar measures already taken, i.e. they should be comparable in scope and nature to measures already taken in equivalent areas in which all scientific data are available,
- based on an examination of the potential benefits and costs of action or lack of action (including, where appropriate and feasible, an economic cost/benefit analysis),
- provisional in nature, i.e. subject to review in the light of new scientific data, and
- capable of assigning responsibility for producing the scientific evidence necessary for a more comprehensive risk assessment.

In this definition, the Precautionary Principle is "risk-oriented", in that it requires an evaluation of risk research including cost-benefit considerations. It is clearly intended for use in drafting provisionary responses to potentially serious health threats, until adequate data are available for more scientifically based responses.

■ The State of EMF Science

The use of electricity has continued to grow throughout the industrialized world since the first public power station began operation over 100 years ago. Today, developing nations look to electricity as a primary means of creating jobs and improving the quality of life. Though electric power clearly benefits societies in countless ways, concern has been raised about the possible adverse health effects from electric and magnetic fields produced during its generation, delivery, and use. In the face of uncertainty, public concern about EMF, as well as the ubiquity of EMF exposure and thus the potential for an appreciable public health impact associated with even a small risk, has led to suggestions that the precautionary principle be adopted.

■ Scientific Uncertainty

While the precautionary principle applies by definition to situations characterized by scientific uncertainty, its application to the EMF issue is especially problematic owing to several specific aspects of EMF science. EMF science involves not only uncertainty as to whether or not exposure is associated with increased risk, but additional uncertainties as well.

First is uncertainty about the magnitude and specificity of the risk.

Another important uncertainty is that it is at present unknown which aspect of exposure might be harmful.

The absence of a clearly elucidated, robust, and reproducible mechanism of interaction of EMF with biological systems and the plethora of field characteristics that could be relevant make avoidance strategies that fall short of avoiding EMF exposure entirely (which could be accomplished only by not using electricity at all) both difficult to formulate and potentially counterproductive.

■ Application of the Precautionary Principle to EMF

Governments have responded to the EMF issue in very different ways. While most have not established any standards for EMF exposure, others have developed guidelines, set local limits, or adopted a policy of prudent avoidance.

■ EMF Guidelines and Limits

A number of national and international organizations have formulated guidelines establishing limits for occupational and residential EMF exposure. These organizations include the International Radiation Protection Association/International Non-Ionizing Radiation Committee (IRPA/INIRC, 1990), the Comité Européen de Normalization Electrotechnique (CENELEC, 1995), the National Radiological Protection Board in the United Kingdom (NRPB, 1993), Deutsches Institut für Normung-Verband Deutscher Elektrotechniker (DIN/VDE, 1995), the American Conference of Governmental Industrial Hygienists (ACGIH, 1996), and the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998). Guidelines focus on prevention of acute neural and cardiac effects. Evidence of potential long-term effects such as cancer is considered insufficient for guideline formulation.

In the U.S., several state and local governments have adopted electric and magnetic field limits for transmission lines (Sahl and Murdock, 1997). These limits, established by regulations in some states (e.g., Florida) and by informal guidelines in others (e.g., Minnesota), are on the order of 10 kV/m within rights-of-way and 2 kV/m at the edge of rights-of-way for electric fields and around 200 mG for magnetic fields. Much more stringent limits for magnetic field exposure (on the order of 2–4 mG at the edge of rights-of-way) have been adopted in some local ordinances.

■ Prudent Avoidance

More frequently than guidelines, governments have adopted "prudent avoidance," a concept introduced by M. Granger Morgan, H. Keith Florig, and Indira Nair at Carnegie Mellon University. In a 1989 U.S. Office of

Technology Assessment (OTA) report (Nair et al., 1989), they suggested prudent avoidance as a policy option. The report defined prudent avoidance as "taking steps to keep people out of fields both by rerouting facilities and redesigning electrical systems and appliances;" prudence was defined as "undertaking only those avoidance activities which carry modest costs." Introduced as "an example of using incomplete science to make a reasoned judgment in the face of uncertainty," prudent avoidance can be seen as an application of the precautionary principle, which calls for taking simple, easily achievable, low-cost measures to minimize exposure even in the absence of a demonstrable risk.

Since its introduction, prudent avoidance has been adopted in Australia, Sweden, and several U.S. states, including California, Colorado, Hawaii, New York, Ohio, Texas, and Wisconsin. Other states, such as Connecticut and Missouri, and the District of Columbia have rejected a policy of prudent avoidance because of insufficient evidence and lack of scientific consensus on the EMF issue.

In the U.S., prudent avoidance has been interpreted to mean everything from adopting the best available practices to implementing low-cost steps (defined in California as actions costing less than 4% of a project budget) in constructing new lines. Most recently, the National Institute of Environmental Health Sciences (NIEHS) report stated that "the NIEHS believes that there is weak evidence for possible health effects from ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged." While noting that aggressive regulatory concern is not warranted, because the use of electricity and therefore exposure to ELF-EMF is ubiquitous, the report states that "passive regulatory action is warranted such as a continued emphasis on educating both the public and the community on means aimed at reducing exposures."

Prudent Avoidance has not been formally adopted in the US for regulation of communications or commercial broadcasting facilities. However, government agencies have made recommendations to the telecommunications industry that could be considered as forms of Prudent Avoidance. In 1999 the U.S. Food and Drug Administration (FDA) urged the mobile phone industry to design phones that minimize user exposure to RF fields to levels necessary for the device's function.

In Prudent Avoidance, as implemented by various countries, prudent refers to expenditures, not an attitude to risk. It does not imply setting exposure limits at an arbitrarily low level, and requiring that they be achieved regardless of cost, but rather adopting measures to reduce public exposure to EMF at modest cost. There is no requirement for assessment of potential health benefits.

ALARA is an acronym for As Low As Reasonably Achievable. It is a policy used to minimize known risks, by keeping exposures as low as reasonably possible, taking into consideration costs, technology, benefits to public health and safety and other societal and economic concerns. ALARA today is mainly used in the context of ionizing radiation protection, where limits are not set on the basis of a threshold, but rather on the basis of "acceptable risk". Under these circumstances, it is reasonable to minimize risk that can be presumed to exist even at levels below recommended limits, on the grounds that what constitutes "acceptable risk" can vary widely among individuals.

The Precautionary Principle and EMF Policy: Specifics

Application of the precautionary principle to EMF policy has several unique and interesting aspects; among them are the use of everyday exposure levels as a benchmark, the distinction between new and existing electrical facilities, exposure to children, and the involuntary nature of the exposure. Several risk tradeoffs are also involved.

Since, as discussed above, it is presently unknown what, if any, levels or characteristics of exposure might be harmful, several applications of the precautionary principle have used existing EMF exposure levels as a benchmark (National Board of Occupational Safety and Health, 1996). Similarly, the New York Public Service Commission limits new construction to designs "that produce magnetic fields no stronger that those already common throughout the state" (Stilwell, 1996).

Limiting application of the precautionary principle to new facilities is common to most policies that have adopted it. Implicit in the focus on new facilities is consideration of costs, which are typically higher for retrofitting existing facilities than for modifying the design of new ones. Because the epidemiologic evidence for EMF effects has been strongest for childhood leukemia and because children are often afforded extra protection, some proponents of the precautionary principle have suggested that special consideration be given to schools and day-care facilities (as, for example, in Sweden). Formal policy analysis, which includes cost-effectiveness calculations, would also tend to give more weight to exposure to children because of the increase in potential lost years of life.

Tradeoffs to consider include the potential for risk offset, risk substitution, risk transfer, and risk transformation (Graham and Wiener, 1995), as well as benefits and costs.

Finally, voluntary and involuntary sources of exposure carry different risk perception implications (Slovic, 1987); if an exposure is viewed as involuntarily imposed,

perceived risk increases. Although the concept of prudent avoidance spans suggestions for personal or voluntary exposures as well as those perceived as involuntarily imposed, most of the so-far-adopted policies focus on exposures that are regarded as involuntary.

Another difficulty is the ubiquity of EMF exposure in modern society, at highly variable levels and over wide frequency ranges. It is therefore difficult to create cautionary policies that have consistency and equity. For example, typical urban environments contain a multitude of radiofrequency transmitters, ranging from low power communications transmitters to very high power broadcast transmitters. It is difficult to envision a consistent and equitable cautionary policy that would minimize radiofrequency EMF exposures from cellular telephone base stations given the presence of far higher powered sources in the same urban area. Indeed, attempts to implement a cautionary policy for cellular telephone masts have typically been done on a piecemeal basis, with no attention to other (much stronger) sources of RF energy in the environment.

It is possible to introduce cautionary policies without undermining science-based standards. In 1999, the New Zealand Government issued their RF exposure standards that follow the 1998 ICNIRP EMF guidelines. The Ministries of Health and Environment noted that it considered the basic restrictions and reference levels in its standard to "provide adequate protection". However, the Ministries noted that community concerns over RF exposure might be addressed by "...minimizing, as appropriate, RF exposure which is unnecessary or incidental to achievement of service objectives or process requirements, provided that this can be readily achieved at modest expense". This emphasis on reducing exposure at "modest expense" with no evidence of prospective health benefits or cost-benefit analysis, marks this policy as a form of prudent avoidance, not an application of the Precautionary Principle as outlined by the European Commission.

■ Discussion

As it has been implemented in EMF policy, the precautionary principle—or, more specifically, prudent avoidance—has been criticized as going too far and not far enough. Risks are always present in all aspects of our lives and there is always some uncertainty associated with those risks. We as individuals and as a society can and do make decisions under uncertainty. And while the possibility of risk does not in itself justify action, uncertainty does not in itself justify inaction. Rather, both a proposed precautionary action and its alternative (not taking that action) should be evaluated in terms of the probability of false-positive and false-negative errors and their consequences. When societal losses from false-negative errors are more compelling than losses from false-positive errors, precautionary action is justified.

The precautionary principle is vague and at best can provide a general framework. . Additional decision rules are necessary as a guide to whether actions should, in fact, be taken in the face of uncertainty in a given situation and, if so, which action among competing alternatives should be chosen. Such guidance should be based on consideration of tradeoffs and cost-benefit analysis.

Both the benefits of electricity and other newer technologies such as mobile phones, as well as potentially enormous mitigation costs, easily justify the need for better scientific knowledge for more informed decisions.

Because it is unlikely that any one alternative will be preferred with respect to all of the objectives, defining objectives for decisions is vital, as is accepting that it will probably be necessary to make tradeoffs among those objectives. Other criteria will need to be developed and applied and might depend on the specifics of who is practicing the precautionary principle and in what setting. How prescriptive these criteria are will depend on whether an individual, an industry, or a government is applying the precautionary principle, as well as whether human health or the environment are to be protected.

Both science and judgment play a pivotal role in any evaluation of risk. Adoption of the precautionary principle does not eliminate, and perhaps increases, the need to reduce uncertainty. Any such policy should provide for means to monitor and refine the consequences of action, as decisions made in the face of uncertainty will not be right all the time.

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EMF EXPOSURE STANDARDS IN NEW ZEALAND

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■ Abstract

Recommendations for limiting exposures to EMF* in New Zealand are based on ICNIRP guidelines[1]. The ICNIRP guidelines form the basis of the New Zealand radiofrequency field exposure Standard NZS 2772.1:1999, which covers the frequency range 3 kHz – 300 GHz. The Standard also provides guidance on verification of compliance, and requires exposures to be minimised, provided that this can be achieved at modest expense.

The Standard is not cited in any legislation, and so has no formal legal status. However, the Ministry of Health recommends strict application of the Standard as a means of controlling exposures to RF fields, and the implementation of low or no cost measures to minimise exposures. The Ministry for the Environment has recommended that compliance with the Standard be a requirement in local authority planning rules for radio transmitters.

There is no Standard or similar document covering frequencies below 3 kHz. The Ministry of Health recommends compliance with the ICNIRP guidelines at these frequencies too, and several local authorities have incorporated ICNIRP guidelines in planning rules concerning power lines and other electrical installations.

■ Background to the New Zealand RF field exposure Standard

The National Radiation Laboratory (NRL), a unit of the Ministry of Health responsible for administering ionising radiation protection legislation, has since the 1970s been the government agency providing advice to government, industry and the public on possible health effects from EMFs. In the absence of any national Standard, NRL advice was based on overseas recommendations such as the 1982 ANSI and 1988 INIRC/IRPA exposure limits.

Public interest and concern in New Zealand as elsewhere about possible health effects of exposure to EMFs developed over the 1980s. This concern came to a head in 1990 with proposals to expand a major transmitter site just west of Auckland, and led to the Minister of Broadcasting directing Standards New Zealand (then called the Standards Association of New Zealand) to prepare a New Zealand radiofrequency field exposure Standard.

As an interim measure, the new RF Standard committee set up by Standards New Zealand adopted the existing Australian RF exposure Standard (AS 2772.1:1990) as NZS 6609.1:1990†. This Standard was based on the 1982 ANSI C95.1 Standard, but made some significant changes, including:

Reduced limits for non-occupational exposures – Non-occupational exposure limits were set at one-fifth of the occupational levels, in accordance with the IRPA 1998 proposals.

Exposure limit constant above 30 MHz – Whereas the ANSI exposure limit increased at frequencies greater than 300 MHz, the AS 2772/NZS 6609 limits for occupational and non-occupational exposures remained flat up to 300 GHz. According to the Standard's rationale, this was because of WHO references to injuries to rabbit eyes caused by short term exposures (less than one hour) to RF fields at 35 and 107 GHz at power flux densities ranging from 50 to 6000 W/m^2. On the other hand, it has also been suggested that the limits at these frequencies were negotiated between parties with differing views on where they should be set[2].

Dual limits below 9.5 MHz – Dual occupational limits were set at frequencies below 9.5 MHz. If there was no possibility of RF burns and shock, the limits were the same as the ANSI values. In other situations, lower limits were applied to prevent shocks and burns

Reduced averaging time – The averaging time for exposures was reduced from six minutes to one minute. The reason presented in the rationale was that:

> "The committee was concerned that because this [six minute] averaging time allowed relatively high exposures at the beginning of the period, even when followed by low exposures, such high exposures could lead to a high possibility of athermal effects being manifest. It agreed that a shorter averaging time was prudent, and adopted a value of 1 min."

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* In this paper, "EMF" means electromagnetic fields in the frequency range 0 – 300 GHz, consistent with the WHO definition.

† A list of New Zealand RF Standards, with complete references and the Standard they were based on, is presented in Table 2 at the end of this paper.

ALARA requirement for non-occupational exposures – In addition to exposure limits for non-occupational exposures, the Standard stated:

> "...because the effects of such exposures to electromagnetic fields are only imperfectly understood, it is recommended that the levels of all electromagnetic fields to which people are non-occupationally exposed, should be kept *as low as reasonably achievable*." (italics in the original)

The use of a phrase introduced specifically for ionising radiation protection, where it has a particular meaning and clear scientific basis, was unfortunate due to the risk of diluting its meaning, and perhaps giving an impression that there might be a similarity between the effects of ionising and radiofrequency radiations. It is clear from the Standard's rationale that the intention of this clause was to require exposures to be minimised, rather than suggest any analogy with ionising radiation.

As part of the process of harmonising Standards with Australia, the Australian and New Zealand committees were amalgamated in 1991 to work on a joint RF field exposure Standard. In 1998 this committee issued an interim Standard (AS/NZS 2772.1(Int):1998), valid for one year, based on the 1988 IRPA guidelines but with limits lower than IRPA at frequencies greater than 400 MHz. The draft of a final Standard was released for public comment in December 1998. This version was based on the 1998 ICNIRP guidelines, and included clauses to aid implementation and verify compliance. There was also a clause requiring operators to minimise exposures to the public.

In the final committee vote on the joint Standard, there were insufficient votes in favour from representatives of either country. It is clear that part of the reason for the negative votes was the move away from a "flat" limit above 300 MHz, and the change in averaging time from one to six minutes.

In accordance with Standards' procedures, efforts were made to resolve differences. The New Zealand committee members, representing the bodies listed in table 1, managed to agree on changes which, when put to a further ballot of the New Zealand members, received sufficient votes to be adopted. The resulting Standard is New Zealand Standard 2772.1:1999 *Radiofrequency Fields Part 1: - Maximum exposure levels - 3 kHz to 300 GHz.*

■ Overview of NZS 2772.1:1999

The New Zealand RF field exposure Standard ("the Standard") is based closely on the ICNIRP 1998 guidelines, and all basic restrictions, reference levels, averaging times, treatments of pulsed and multi-frequency exposures etc are taken directly from ICNIRP. (Indeed, the ICNIRP guidelines form Appendix A of the Standard.)

Adopt Radiation Controls Inc
Broadcast Communications Ltd
Local Government NZ
Ministry of Commerce
National Radiation Laboratory (Ministry of Health)
New Zealand Association of Radio Transmitters
New Zealand Institute of Occupational and Environmental Medicine
Telecom New Zealand Ltd

Table 1. Composition of the NZ RF Standard committee

The Standard includes several clauses intended to aid implementation and verification. Amongst these are the following:

Spatial averaging – in order to take account of the fluctuations in field strength caused by interference and other effects, the Standard prescribes how exposures may be spatially averaged.

Verification of compliance – the Standard specifies the measurements required to verify compliance. This includes consideration of near and far fields, type testing, and mobile and portable transmitters. Clarifying how compliance should be verified, especially in respect of time averaging exposures, was one of the changes which led to final adoption of the Standard.

Protective measures – the Standard outlines the types of measures which should be used to ensure protection for both occupational and public exposures.

Amongst the controls for protection of the general public is clause (10(d)) which requires:

> "Minimizing, as appropriate, RF exposure which is unnecessary or incidental to achievement of service objectives or process requirements, provided that this can be readily achieved at modest expense."

The basis for this clause is presented in the Foreword to the Standard, which states:

> "There is a currently a level of concern about RF exposure, which is not fully alleviated by existing scientific data. It is acknowledged that data regarding biological effects, at levels below those determined in this Standard, are incomplete. However, as these data are neither clear nor consistent, these have not been used in setting levels in the ICNIRP guidelines or this Standard. It should be further noted that it is not possible to logically prove with certainty that any environmental agent will not cause an adverse health effect. This is an inherent limitation of any process,

including the scientific method, that relies on inductive reasoning.

Research is continuing in many countries into possible effects on health arising from RF exposure. In recognition of this, the committee will continue to monitor the results of this research and, where necessary, issue amendments to this document. Generally, it is therefore sensible in achieving service or process requirements to minimise unnecessary or incidental RF exposure."

The exact wording of this clause, and the discussion in the Foreword, was debated extensively by both the joint and New Zealand committees, and it carries over the "*as low as reasonably achievable*" requirement from NZS 6609. A note below clause 10(d) comments:

"Although ICNIRP considers that the basic restrictions and reference levels in this Standard provide adequate protection, it is recognised that community concerns over RF exposure may be able to be addressed by further minimisation of exposure in accordance with the requirement of item (d)."

■ Legal status of the Standard

The Standard is not cited in any New Zealand law or regulations, and so has no explicit legal standing. However, the New Zealand Ministry of Health recommends strict application of the Standard as the basis for controlling exposures, on the grounds that:

- The ICNIRP guidelines incorporated in the Standard are based on a recent and comprehensive evaluation of the research literature.
- The ICNIRP conclusions and guidelines are supported by other independent reviews published by competent and experienced panels.
- The Standard includes clauses to assist with implementation and demonstration of compliance.

The Ministry also supports the implementation of low or no cost measures to avoid or reduce exposures, as envisaged in clause 10(d) of the Standard. Effectively, this means that if different options are available when a transmitter is being planned, then those which result in the lowest exposures should be preferred, all other things being equal. For example, this could be by choosing an antenna which minimises transmissions in directions where coverage is not required, and using the minimum power necessary to achieve the required coverage. It may involve a trade-off between competing objectives: for example, raising an antenna further off the ground would decrease exposures, but may make it more visually intrusive. If two equally suitable sites are available, the one resulting in lowest exposures should be chosen.

The Ministry considers that such low or no cost measures are appropriate for a number of reasons, including the acknowledged gaps in research and understanding in some areas. The measures should not be seen as undermining the ICNIRP guidelines, but as a means to take account of the remaining uncertainties in our understanding of the science, and the assumptions inherent in the ICNIRP and other risk assessments.

On the advice of the Ministry of Health, National Guidelines issued by the Ministry for the Environment (MfE)[3] recommended to local authorities that compliance with the New Zealand RF field exposure Standard be included in local planning rules relating to radio transmitters. The MfE Guidelines were produced at the request of central government in order to assist local authorities, many of which felt poorly equipped to assess the health arguments arising from the introduction of new radio technologies (principally cellular). Community groups and the telecommunications industry were consulted extensively during development of the guidelines, which provide advice to these parties as well as local authorities.

Although the MfE Guidelines are not binding on local authorities, they include a discussion of relevant decisions from the Environment Court (the appeal court for planning matters, whose decisions can have some precedent value) which in 1999 determined that the Standard should not be undermined without good reason[4]. Many local authorities are now following the MfE advice, or have based their rules on previous versions of the Standard. While some members of the public still consider that more restrictive exposure limits should be applied, the publication of clear guidance from the two Ministries has helped clarify which issues may fruitfully be raised at planning hearings, and has probably resulted in several decisions not to proceed with appeals to the Environment Court.

Under the Health and Safety in Employment Act, employers are responsible for identifying and controlling workplace hazards. There is no explicit requirement to comply with the Standard but the NRL, which often provides advice on such matters to both individual employers and the Occupational Safety and Health service of the Department of Labour, recommends its application here too. In this context, it is important to distinguish between "true" occupational exposures (that is, exposures to people who are exposed in the course of their work, are aware of the exposures and also of any safety precautions that might be necessary), and incidental exposures of other staff who should properly be considered as members of the public.

Major employers in businesses where RF exposures can occur are generally well aware of possible hazards and take appropriate measures to identify areas of high exposure, control access, limit exposures and train staff. The situation with smaller businesses using RF heating or

welding equipment is not so clear. A survey carried out in the late 1980s found a high percentage of RF welders exposed operators to field levels well above reference levels. Since then, many of the welders producing high exposures have been withdrawn or modified. Most welders in NZ are supplied and serviced by one company, which considers itself legally obliged to check exposures from any equipment it handles. However, no further work has been carried out to determine whether the problem of high exposures has been eliminated.

Other frequencies

There are no New Zealand Standards or other documents covering frequencies below 3 kHz. NRL advice has normally been to follow ICNIRP guidelines and since the late 1980s, for example, has recommended IRPA/INIRC (and more recently ICNIRP) guidelines for exposures to power frequency fields. Some local authorities have incorporated the ICNIRP guidelines applying at 50 Hz to planning rules governing power lines and other electrical installations.

Discussion

At the time the 1999 Standard was introduced, some argued that the increase in exposure limits at frequencies above 400 MHz would lead to higher public exposures. In practice there is no evidence that this has happened. At these frequencies, maximum exposures in public areas were already considerably below the limits in previous versions of the Standard, and there is no reason to believe that operators then or now were constrained by the exposure limits. Occupational practices and exposures, however, have changed in response to changes in the Standard. (In some situations, occupational compliance is now more difficult than previously, due to the disappearance of some short term relaxations present in the old NZS 6609.)

There are no hard and fast rules to determine whether a proposed transmitter satisfies the clause 10(d) requirement to minimise exposures. For some applications, such as cellular phone base stations (cellsites), the technology itself often requires that transmitter power be minimised in order to prevent radio interference. There have certainly been examples of cellular network operators making adjustments to proposed antenna locations in order to reduce exposures, and even locating cellsites away from optimal sites which were within or very close to residential areas. As part of the planning process, some sites have been subjected to very close scrutiny to test whether they satisfy clause 10(d).

A concern frequently expressed during preparation of the MfE Guidelines was that they could not take account of any future research which might lead to a change in the exposure recommendations. In response to this concern the Ministry of Health undertook to broaden the scope of an existing interagency committee which monitors research on extremely low frequency fields to include RF fields as well. The new terms of reference of that committee require, amongst other things, that it inform the Director General of Health of any developments which affects policies, guidelines and advice promulgated by the Ministry of Health and Ministry for the Environment.

In common with many small countries, it would be difficult for New Zealand to develop EMF exposure Standards independently from scratch. It is invaluable to have comprehensive and credible guidance available from organisations such as ICNIRP to form the basis of such Standards.

Table 2. New Zealand radiofrequency field exposure standards, and their bases

Standard	**Standard used as a basis**
AS 2772.1:1990 Adopted as NZS 6609.1:1990 *Radiofrequency fields Part 1 - Maximum exposure levels 100 kHz – 300 GHz*	American National Standards Institute. Safety levels with respect to human exposure to radiofrequency electromagnetic fields, 300 kHz – 100 GHz. The Institute of Electrical and Electronics Engineers, New York NY10017, ANSI Committee C95.1, 1982.
AS/NZS 2772.1(Int):1998 *Radiofrequency fields Part 1 - Maximum exposure levels 3 kHz - 300 GHz*	IRPA (1988). Guidelines on limits of exposure to radiofrequency electromagnetic fields in the frequency range from 100 kHz to 300 GHz. Health Physics, 54:115-123
NZS 2772.1:1999 *Radiofrequency fields Part 1: - Maximum exposure levels 3 kHz - 300 GHz*	ICNIRP (1998). Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics 74 (4), 494-522

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Electromagnetic Field (EMF) Exposure Standard in China

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■ Current RF EMF Exposure Standards in China Rationale for RF EMF Exposure Standards

(1) The basic consideraion: Assessment of health hazard for setting standards should rely mainly on the health status of personnel exposed to RF EMFs. The results of experimental animals and theoretical calculation should be supplemented to the human exposure data. In this cases, we may evaluate whether the really exposure levels are safe.

(2) Some investigations on the health effects of occupational and environmental exposure to different frequency band were performed in China. The results showed that chronic exposure to EMFs are associated with a variety of non – specific symptoms, including increased frequency of neuroses, liability of vegetation nervous system, and slight changes in peripheral blood, lens, and non – specific immune function. These effects seem to be similar to human acute reaction to microwave exposure, similar to some animal experiments, and similar to other investigations conducted in some foreign countries. But there exist many uncertainties in assessment of health hazards related to exposure to EMFs. The health hazard develops after overpassing of the adaptation/defense processes of the subjects. However, the existence of health hazardous effects of RF and MW could not be denied. The threshold levels for occupational exposure at 0.1 – 30 MHz are in the range of 20 – 100 V/m; at > 30 MHz, in the range of 50 – 200 uW/cm^2.

(3) Animal experiments. Under certain well controlled conditions of exposure, a variety of behavioral, neurological, reproductive abnormalities, and DNA damage were demonstrated. Evidence for biological effects at SAR threshold of the following values were observed:

·Changes in behavior
SAR=0.6W/kg
·Decrease in choline uptake in brain
SAR=0.45-0.75W/kg
·Changes in brain energy metabolism
SAR=0.1W/kg
·Changes in hematological and immunology system
SAR=0.5W/kg
·Chromosome aberration and DNA damage
SAR=1.0-1.2W/kg

(4) Possibility to meet the standards at no cost or low cost.

■ RF Exposure Limits

(1) General public exposure limits to RF in China were shown in Tab.1

Tab.1 General Public Exposure Limits to RF Radiation in China (Ministry of Health, HM)

Frequency	Exposure limits	
	First class	Second class
0.1-30 MHz	10 V/m	25 V/m
>30-300 MHz	5 V/m	12 V/m
>0.3-300 GHz	10μW/cm^2	40μW/cm^2

First class exposure limits: Below these levels are safe for permanent exposure and for all people(including infants, pregnant women, old people, patient, etc.)
Second class exposure limits: Below these levels a temporary dwelling of human subjects is allowed (factories, organs, parks, recreative areas, etc.). However, living quarters, hospitals, schools, kindergartens, etc. are not allowed to be located.

(2) The occupational exposure limits to RF at different frequency band are shown in Tab. 2 – 4.

Tab. 2 Occupational Exposure Limits to 0.1-30MHz Radiation in China (HM)

Frequency (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)
0.1-3.0	50	5
>3.0-30	25	-

Tab. 3 Occupational Exposure Limits to >30-300MHz Radiation in China (HM)

	CW	PW
8-hour day exposure	0.05mW/cm^2 (14V/m)	0.025mW/cm^2 (10V/m)
4-hour day exposure	0.1mW/cm^2 (19V/m)	0.05mW/cm^2 (14V/m)

Tab.4 Occupational Exposure Limits to MW Radiation in China (HM)

CW or PW(rotating):	
400μWh/cm^2	(for a working day)
50μW/cm^2	(for 8 hrs daily)
PW(stationary):	
200μWh/cm^2	(for a working day)
25μW/cm^2	(for 8 hrs daily)
Extremities Exposure:	
4 mWh/cm^2	(for a working day)
0.5 mW/cm^2	(for 8 hrs daily)

It is worth noting that these occupational exposure limits are

only for working places, and not for EMF – generating devices. Considering the health effects of RF exposure related to the exposure intensities and the duration of exposure, and various exposure duration for occupational exposure, the daily exposure dose limits are adopted in the occupational exposure standards.

Compared with continuous wave radiation, pulsed microwave with the same frequency and the same average power density are general more effective in producing a biological effect. Stricter exposure limits are adopted for pulsed microwave exposure in the occupational exposure standards.

(3) EPA proposed another RF exposure standard. The exposure limits of the regulation are derived from SARs. The SAR should be less than 0.02 W/kg for general population (Tab.5), and less than 0.1 W/kg for occupational exposure.

Tab. 5 Exposure limits to RF for general population in China (EPA)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (W/m^2)
0.1 ~ 3	40	0.1	(40)
3 ~ 30	$67/\sqrt{f}$	$0.17/\sqrt{f}$	(12/f)
30 ~ 3000	(12)	(0.032)	0.4
3000 ~ 15000	($0.22\sqrt{f}$)	($0.001\sqrt{f}$)	f/7500
15000 ~ 30000	(27)	(0.073)	2

Note: (1) The limits are derived from SAR=0.02 W/kg
(2) Figures in parentheses are provided for information only

■ Draft of the Amended EMF Exposure standard in China

The current RF EMF exposure standards in China have been performed for over 10 years. They have promoted many valid measures to reduce significantly the exposure levels in work places and in environment in China. However, because of the new and rapid development of telecommunication facilities, the economic globalization, and the need for standard harmonization, a draft of the amended EMF exposure standard was proposed by an United Working Group in China. The draft will be further discussed and determined after public review.

(1) As ICNIRP guidelines, the EMF standard draft covers the entire frequency ranges of time-varying EMF and static magnetic field. Also there are two classes, i.e. basic restrictions and reference levels, and the basic restrictions on exposure are current density, SAR (including whole-body average SAR and localized SAR), and power density. Two tier standards, i.e. occupational and general public, are also adopted.

(2) The main differences between ICNIRP and the draft are as follows:

A. ICNIRP guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, and elevated tissue temperature resulting from absorption of energy during exposure to EMF (thermal effects). However, there is a body of literature, which suggests that biological effects can be shown at levels of radiation, which do not produce heating or stimulation. For nonthermal chronic RF exposure, for example, neurologic symptoms, changes in behavior and cardiovascular system, etc. in occupational exposure workers have been reported in many different countries by some cross sectional epidemiological studies and animal experiments. Though their mechanisms have not been understood yet, many studies in vivo and in vitro have confirmed at least that the EMF exposure at the levels lower than the ICNIRP guidelines may cause stress effect. And chronic expression of heat stress proteins is reported to be associated with health hazards. Since there are many potential long-term effects, more stringent basic restrictions than ICNIRP's are adopted in the draft of the amended exposure standard in China (Tab.6,7). The reference levels of the standard are being discussed.

Table 6. Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.* (draft)

Exposure Characteri-stics	Frequency range	Current density for head and trunk ($mA\ m^{-2}$) (rms)	Whole-body average SAR ($W\ kg^{-1}$)	Localized SAR (head and trunk) ≤2h	Localized SAR (head and trunk) >2h	Localized SAR (limbs) ≤2h	Localized SAR (limbs) >2h
Occupational exposure	up to 1 Hz	10	—	—	—	—	—
	1-4 Hz	10/f	—	—	—	—	—
	4 Hz-1 kHz	2.5	—	—	—	—	—
	1-100 kHz	f/400	—	—	—	—	—
	100 kHz-10 MHz	f/400	0.1	5.0	10/t	10	20/t
	10 MHz-10 GHz	—	0.1	5.0	10/t	10	20/t
General public exposure	up to 1 Hz	2.0	—	—	—	—	—
	1-4 Hz	2.0/f	—	—	—	—	—
	4 Hz-1 kHz	0.5	—	—	—	—	—
	1-100 kHz	f/2000	—	—	—	—	—
	100 kHz-10 MHz	f/2000	0.02	1.0	$1.2/t^{1/4}$	2.0	$2.4/t^{1/4}$
	10 MHz-10 GHz	—	0.02	1.0	$1.2/t^{1/4}$	2.0	$2.4/t^{1/4}$

*Note: 1. f is she frequency in hertz.
2. Localized SAR averaging mass is any 10 g of contiguous tissue.

Table 7. Basic restrictions for power density for frequencies between 10 and 300 GHz.*

Exposure characteristics	Power density (W m^{-2})
Occupational exposure	6
General public	2

*Note:
1. Power densities are to be averaged over any 20 cm^2 of exposed area and any $68/f^{1.05}$-min period (where f is in GHz).
2. Spatial maximum power densities, averaged over 1 cm^2, should not exceed 20 times the values above.

B. Exposure time is a key factor in how much exposure a person receives within a day. Many studies indicated that the bioeffects of EMF exposure are related to the exposure intensity and duration of exposure. In fact, some localized exposure, e.g. the exposure duration of mobile phone user is usually less than one or two hours per day. The basic restriction for such short time exposure should be different from longer time exposure, that is adopted in the draft of the amended standard. And for occupational whole-body exposure, there are various but regular exposure duration, then in the draft, the EMF permissible exposure reference levels for shorter time exposure are also higher than that of 8 h per day exposure.

(3) The present knowledge in assessment of possible health effects related to exposure to EMF have not provide sufficient rationale for establishing satisfactory and general acceptable exposure limits. The draft of the amended exposure standard in China is also questionable and far from perfection. However, as the rapid development of molecular biology, researches using powerful techniques, such as genomic, proteomics, and others may settle many arguments about the health effects of EMFs. We can identify and understand the mechanism of the effects including biomolecular and sub-cellular effects caused by exposure to low level EMF. On the other hand, we think that it is better for now to provide adequate of protection taking easily achievable, low cost measures to reduce EMF exposure, especially for newly built housing and electrical facilities. However, the EMF exposure standard will be revised as the advances are made. The harmonization of EMF standard worldwide might be performed after finishing WHO 's international EMF research project, and developing of the bioelectromagnetics.

EMF SAFETY STANDARDS IN JAPAN

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Not Available

EMF SAFETY STANDARDS IN MALAYSIA

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EMF Standards and Researches in Korea

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■ INTRODUCTION

Public concerns associated with power lines, mobile phones and base stations have been increasing. However, this phenomenon has arisen mainly from the press reports which have not been based on the exact knowledge of the health effects from the electromagnetic field (EMF) exposures in many cases. This has caused to prevail that EMF facilities would be hazardous. The number of petitions filed in 2000 reached to 120 cases for the power lines and 152 cases for the base stations. Some of them argued that symptoms were too severe to be able to live normally.

Details of EMF standards and policies will be discussed. In addition, EMF researches including dosimetry, in vivo and in vitro studies for EMF exposures, and epidemiological study in Korea will be introduced in the following sections.

■ EMF STANDARDS AND POLICIES

In December 1999, the article 47-2 of "The Radio Wave Act" was revised in the National Assembly in order to enact a provision for protection from the EMF exposures and then it was proclaimed in January 2000. Furthermore, in December 2000, the Ministry of Information and Communication (MIC) of Korea announced officially four separate ordinances for exposure limits: measurement methods for EMF intensities and specific absorption rate (SAR) values, and installations and devices to which the exposure limits apply. They will be enforced from 1 January 2002.

The exposure limits of the electric and magnetic fields in the frequency ranges up to 300 GHz are regulated in the ordinance (see Table 1 & 2). The SAR values for mobile phones are also regulated in the frequency ranges between 100 kHz and 10 GHz. The exposure limits for EMF intensities follow the ICNIRP guideline and the SAR limits are based on the IEEE/ANSI guideline. The ordinances, except the SAR limit for mobile phones, are not mandatory but recommendatory. Precautionary policies have not been adopted yet in Korea.

Regarding the mobile phones, it is planned that the SAR values for each mobile phone available on the market will be measured and then the results will be published by the end of this year. The government has also adopted a mandatory rule to restrict the use of mobile phones in moving vehicles. Hands-free devices should be used while driving. The law has been enforced on 1 July 2001. For the public, a booklet of "EMF in Everyday Life and Human Protection" has been published by the MIC in cooperation with the expert group in Korea.

[Table 1] EMF exposure limits for the public[1]

Freq Range	E-field strength (V/m)	B-field strength (A/m)	B flux density (μ T)	Power density (W/m^2)
< 1Hz	–	320,000	40,000	
1Hz – 8Hz	10,000	320,000/f^2	40,000/f^2	
8Hz – 25Hz	10,000	4000/f	5000/f	
25Hz – 800Hz	250/f	4/f	5/f	
0.8kHz – 3kHz	250/f	5	6.25	
3kHz – 150kHz	87	5	6.25	
150kHz – 1MHz	87/√ f	0.73/f	0.92/f	
1MHz – 10MHz	87/√ f	0.73/f	0.92/f	
10MHz – 400MHz	28	0.073	0.092	2
400MHz – 2GHz	1.375√ f	0.0037√ f	0.0046√ f	f/200
2GHz – 300GHz	61	0.16	0.20	10

[Table 2] EMF exposure limits for workers[1]

Freq Range	E-field strength (V/m)	B-field strength (A/m)	B flux density (μ T)	Power density (W/m^2)
< 1Hz	–	1.63x10^5	2x10^5	
1Hz – 8Hz	20,000	1.63x10^5/f^2	2x10^5/f^2	
8Hz – 25Hz	20,000	20,000/f	25,000/f	
25Hz – 820Hz	500/f	20/f	25/f	
0.82kHz – 65kHz	610	24.4	30.7	
65kHz – 1MHz	610	1.6/f	2.0/f	
1MHz – 10MHz	610/f	1.6/f	2.0/f	
10MHz – 400MHz	61	0.16	0.2	10
400MHz – 2GHz	3√ f	0.008√ f	0.01√ f	f/40
2GHz – 300GHz	137	0.36	0.45	50

■ EMF RESEARCHES

In 2000, a five-year EMF research project funded mainly by the government has been started. The total amount of the budget will be reached about $8.5m for the duration of the project. Main research topics are as follows: dosimetry, in vivo and in vitro studies for middle frequency (MF) and radio frequency (RF) exposures, epidemiological studies. Several other research projects such as health effects for the extremely low frequency (ELF) exposures have been investigated. It has been supported by other governmental ministries such as the Ministry of Environment and the Ministry of Commerce, Industry and Energy.

For ELF, MF and RF studies, researches have been carried out in Electronics and Telecommunications Research Institute (ETRI), Korea Electromagnetic

Engineering Society (KEES) and Radio Research Laboratory. On the other hand, the ELF studies have been investigated by other research organizations such as Korea Electric Power Company, Korea Electricity Research Institute and Korea Electric Power Research Institute.

Research projects for 2000-2001 are summarized in the following sections.

Dosimetry

Methods for the SAR estimation have been developed. The SAR measurement procedure has been studied in order to determine the peak SAR value in the human head for mobile phones experimentally[2]. An E-field probe for the compliance test of mobile phones has been designed and fabricated[3]. SAR reduction techniques for mobile phones have also been investigated extensively.

SAR for mobile phone exposures has been studied using a numerical analysis method. Especially, effects of the head size on the electromagnetic absorption and a mass-averaging technique for localized SAR such as 1g-SAR or 10g-SAR have been investigated[4]. A numerical phantom using a volunteer with the domestic head shape was also developed. A whole body model is under constructed.

The dielectric properties for pathological tissues cultivated by the xenograft method have been analyzed to model the frequency dispersion behavior of them.

In vivo and In vitro Study

In vivo studies for long-term ELF exposures were investigated. Electric fields at 60 Hz were applied to expose mice up to three generations[5]. For the exposure levels of the ICNIRP guideline, there was no significant health effect. However, for the high level exposure (five times higher than the ICNIRP guideline level), it was found that congenital abnormalities were possible and the immune system and reproduction function would be affected adversely.

Several in vivo studies for MF and RF exposures have been carried out. Rats have been exposed to saw tooth magnetic fields of 20 kHz in order to elucidate the effects of the MF exposures on subacute toxicity, malformation upon gestational age and carcinogenic effects combined with environmental carcinogens.

Human fibroblast cells and T-lymphocyte cells have been exposed to fields of 848.5 MHz and 1.8 GHz which have been used in mobile telecommunications[6]. Cell proliferation and destruction, cell transformations, chromatic aberrations, alterations in gene expression and stress responses have been investigated. It is planned that mice will be exposed to the frequencies of 848.5 MHz and 1.8 GHz in order to investigate the possible causes of adverse health effects.

Epidemiological Study

Epidemiological studies of carcinomas (leukemia, malignant lymphoma, brain tumor, breast cancer) for the residents near AM radio stations were performed[7]. The purpose was to investigate an association between residing near radio broadcast towers and carcinogenic appearance based on a geographical correlation design. Among ten exposed areas, two areas were showed significantly high incidence for leukemia and brain tumor compared to control areas. For malignant lymphoma and breast cancer, however, there were no significantly increased areas. Results suggested the necessity of further analytical epidemiological studies with more precise exposure measurement and information of confounding factors.

For the RF exposures from mobile phones, a cross-sectional symptom survey was carried out[8]. The preliminary result showed that there would be a correlation between the number of phone uses and thyroid carcinoma. However, there was no correlation for brain tumor and breast cancer. Symptoms such as dizziness, nausea, heat perception in cheek, fatigue in eyeball and pain in ears were reported. Positive dose-response relations were observed. Further analytical study with more information of confounding factors will be investigated in the following year.

■ CONCLUSIONS

EMF standards and policies in Korea were introduced. EMF researches including SAR measurements, in vivo and in vitro studies for the EMF exposures and epidemiological studies were also discussed. It is expected that scientific results from the EMF researches in Korea would contribute to the WHO EMF project.

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CELL HYDRATION AS AN ESSENTIAL CELL PARAMETER FOR ESTIMATING THE BIOLOGICAL EFFECT OF ELECTROMAGNETIC FIELD

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Not Available

ROLE OF MODULATION IN DEVELOPMENT OF EMF SOMATIC EFFECTS

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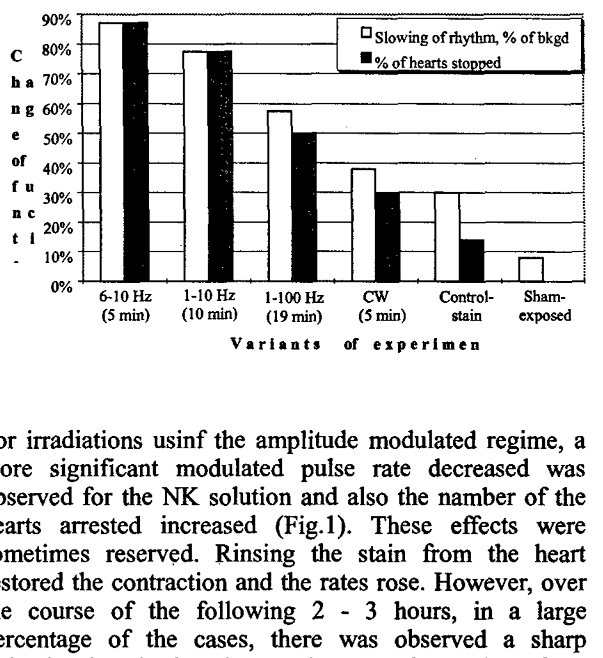
In recent times there has been accumulated an array of data indicating the role of the EMF modulation in development of bioeffects. Nonetheless those results have still not taken their (rightful) place among the essential results to be taken into account in developing standards documents concerning EMF exposure to public.
A great many investigations using different EMF modulation regimes have been carried out in Russia[1- 22]. The analysis of the data indicates that the development of the variety of reactions of the organism is dependent on the form of EMF modulation: changes in behaviour and conditioned reflex activity, influence on bioelectroactivity of the brain, on hormonal status and so on.
We have carried out the investigations which have confirmed the dependence of the development of bioeffects from impulse modulation frequency and have shown the key possibility of "memorizing" the modulated electromagnetic modulated signal in the brain at low S (power density) level [23-25].

■ Investigation of the influence of the modulated EMFs on isolated stained frog hearts. Establishing the role of the initial cardiac rhythm state in the development of bioeffects from exposure to modulated EMF.

A heart in the Ringer's solution ionically equilibrated for cold-blooded tissues can continue to contract for 2 days in the absence of hormonal influence and the central nervous system regulation. That permitted us to investigate it for extended periods of time.
The functional condition was estimated from changes in the frequency of the heart contraction rhythm. The basic morphological criterion for the state of excitable heart tissue was the evaluation of the vital staining process of the interatrial septum structures by the dye azyn-neutral-red (NR). The method of lifetime staning with NR permits vizualization of the viability of heart structures and the state of permeability of its membranes. Another vital stain, methylene blue, was used for estimating the state of cholinergic synapses in the autonomic neurons of the Ludvig node.
Both CW and pulse modulation regimes at low levels of S were used for the electomagnetic irradiation. The carrier frequency was 9.3 GHz. The modulation frequency ranged from 1 to 100 Hz. The pulse shapes used were rectangular, with a pulse duration of 2.5 ms, 50% duty cecle the power density level was 0.016 mW/cm^2. The principle the selected frequencies (sweeping) was used.
All of the basic experiments were carried out during the spring and summer months on 356 puberal frogs - male Pana tempocaria.

Intact unstained hearts (sham series) slowed their rate of contraction by 7 % on average over an observation period of 24 hours. Heart stopping was observed. Half an hour of presence of the isolated heart preparation in the staining solution in and of itself was the cause of changes in its function. The number of slowings decreased even more to 30 % while 14 % of the hearts stopped contracting. Stimulation of arrested hearts with strong light or mechanical agitation of the pacemaker region (sinus venosus) restored their beating. Upon cessation of the process of staining the heart, the rate gradually increased reaching the initial level and only toward the end of the experiment (24 hours later) did the heart contraction rate decrease gradually by an average of 20 % (Fig.1). The reaction of hearts exposed to CW was minimal: bradicardia reached 40%, cardiac arrested- 30%.

Figure 1. Change in the number of beating and stopped isolated frog hearts, EM irradiated using the continuous regime and for various pulse from 1 to 100 Hz



For irradiations usinf the amplitude modulated regime, a more significant modulated pulse rate decreased was observed for the NK solution and also the namber of the hearts arrested increased (Fig.1). These effects were sometimes reserved. Rinsing the stain from the heart restored the contraction and the rates rose. However, over the course of the following 2 - 3 hours, in a large percentage of the cases, there was observed a sharp reduction in tyhe heartbeat and a second stopping of the heart. In these latter cases, stimulating procedures only resulted in short term restoration of heart contractions.
Two to three hours after modulated microwave exposure, disturbances of the granule forming processes in the neurons and muscle fibres of the heart were observed. A large number of the neurons took on an angular form and had a diffuse colaration of the nucleus and cytoplasm. In the muscle fibers the number of granules of dye was reduced, the cytoplasm was lightly stained and many of the muscle cell nuclei were also stained with an intense

red coloration.At the same time gelaatinization of the synapses in the cells of the Ludvig ganglion and intense staining of Schwan cells in the zone of the axon conus were taking place. These kind of chandes indicate disturbances in the viability of the exposed structures of the heart leading to the development of a process like paranecrosis.

<u>The second stage</u> of the investigation to istablish the role of the initial state of the cardiac rhythm in the development of bioeffects in response to the influence of modulated EMF was also carried out on isolated frog hearts. The microwave exposure was short-term with the power density level 0,016 mW/cm^2 and modulation with three variants of frequency sets: a) 20,22,24,25,28 Hz; b) 30,32,34,36,38 Hz; c) 40,42,44,46,48 Hz. The chosen frequency were in accordance with the cardiac rhythm most frequently encountered under our experimental conditions.The esposure duration was 5 min with 1 min at each of the modulation frequencies in the group.

Under these conditions of exposure, changes in the frequency of cardiac contractions were manifesred in practically all cases. In order to carry out analysis of the degree of disturbance in the working og the heart in each of the tree variants of this series of experiments the heart's functioning was evaluated according to the fillowing four point system. Magnitude of chanfe in heartbeat freaquency in % relative to initial magnitude: 10-20% - 1 point; 21-30% - 2 points; more than 31% - 3 points and reversible stopping of the heart - 4 points.

A differential bioeffect dependent on the modulation of the microwave field and associated with the various initial heartbeat frequen cies was obtained (Table 1).

Table 1. Changes in frog heart contraction frequency as a functiion of SHF field modulation and the initial heart contraction frequency

Variant of exposure	Number of hearts	Modulation, Hz	Number of points (average in the group) Initial pulse rate			Point (total)
			20-30	31-40	41-50	
I	23	20,22,24,25,28	50	3	3	56
II	28	30,32,34,36,38	11	12	9	32
III	22	40, 42,44,46,48	9	1	16	26
IV	26	CW	1	-	1	2
control	30	-	-	-	-	0

Most of the heartbeat frequency changes were observed in variant I of the modulation regimes. Beyond that, in each of the modulation regime variants the largest change was associated in a given sample with the initial heartbeat frequency. In variant 1 this was 20-30 beats per minute (modulation frequency 20-28 Hz); in variant II it was 30-40 (modulation frequency 30-38 Hz) and in variant III it was 40-50 (modulation frequency 40-48 Hz).

The data obtained in this series of experiments attests to the usefulness of the notions about functional changes in one system or another as a result of the cooperative action of modulation and carrier EMFs and the possibility of the existence of resonant conditions for the absorption of energy under microwave irradiation.

In summing up the results presented above it must be concluded that in experiments using irradiation of isolated frog heart with microwave fields there was obtained the effect of changing the function of the heart with low power density level (0.016 mW/cm^2). In all the series of experiments involving irradiation of the heart with modulated fields having changing modulation frequencies from 1 to 100 Hz, there was manifested a significantly greater influence on the function of the heart tthan those involving irradiation in a field with a continious regime of generating the EMR.The negativechronotropic effect? which is the established effect of the reversible stopping of the heart during the first three hours after irradiation, was mmore significant and pronounced. The markedness of the changes was associated with the initial state of the heart. Hearts with initial contraction frequencies of 20-30 beats per minute were found to be the most sensitive to the influence of pulse sequences with frequencies of 20-28 Hz.

The analysis of the data from present study indicates that among the mrchanisms of the observed effects, obviously, there are reversible disturbances in the ionic permeability of excitable membranes of the heart with the development of manifistations of a type of cholinergic effect and the electric disconnection of cardiomyocytes. In other worlds a dexrease in the excitability of nervous and muscular elements and a disturbance in the intercellular interaction processes arises from the irradiation of cardiac structure.

The results of studies published earlier about the influence of modulated EMFs on heart are in a agreement with our conclusions [1, 26-28].

■ The influence of modulated low intensity EMFs on imprinting behaviour.

The experiments were carried out on 129 chicks which we irradiated during the period ofembryogenesis with modulated EMFs.

The irradiation conditions for the experimental group, on the 16th day of incubation, were: the carrier frequency was 10 GHz, the pulse modulation was at 10Hz, meander, the pulse duration was 2.5 ms, the exposure time was 5 min and the power dencity level was 40 μW/cm^2. In parallel, we carried out an experiment under the very same conditions except that the irradiation was CW. The third series was the control with "sham" irradiation. The experiments included several repetitions. The EMF exposures were carried out in an anaechoic chamber. Imprinting was carried out one day after hatching and used a light fash imprint stimulus. The differential stimulus differed by 8 Hz. The presence of the imprinting was tested 2 days after hatching using the following criteria: latency in responding to the imprint stimulus; the length of time the chick remained near the imprint stimulus and, the number of approaches to and contacts with the imprint stimulus. Statistical analysis was carried out using Student's test, the Fisher test and other methods.

The results of the experiments carried out are presented in Table 2.

A comparative analysis of the possible action of EMFs with a power density 40 μW/cm^2 on the formation of imprinting in newly hatched chicks showed that, under our experimental conditions, pulse modulated irradiation proved to be more effective. CW electromagnetic irradiation with a power density level of 40 μW/cm^2 did not show *m* an action on imprinting. Imprinting occurred in about 89% of the CW irradiated chicks (it was about 97% in the controls). However, in carrying out analogous experiments with modulated irradiation, imprinting

occurred in only about 50% of the chicks.

Table 2. Formation of imprinting for chicks after irradiation of the embryos with EMFs using continuous and modulated regimes

Set number	Power density, μW/cm²	Time of exposure, min	Name of set	Number of embryos	Number of chicks with imprinting after EM-exposure
1.	-	-	sham-exposed	83	81 (97%)
2.	40	5	CW	27	23 (89%)
3.	40	5	modulated-10 Hz	19	9 (50%)

■ The possibility of fixating a modulated electromagnetic signal in the embryonic chick brain.

Imprinting was chosen as the model for investigating the problem. The experiments were carried out on 127 embryonic chicks on the 16th day of incubation. The embryos were irradiated with EMFs in an anaechoic chamber: carrier freaquency 10 GHz, powe density level 0.04 mW/cm² with pulsed modulations of 1, 2, 3, 7, 9 and 10 Hz. The overall duration of each irradiation was 5 min.

Keeping in mind that we were proceeding from the proposition that a modulated electromagnetic signal could be "memorized" by the brain and take on the role of an imprinting signal, the sensitive period for imprinting (24 h after hatching) was skipped. During this period no external stimuli were presented to the chicks. However, 48 h after hatching we presented the chicks with a pseudo imprint stimulus in the form of a blinking light using the same frequency as the embryo was subjected to through the electromagnetic irradiation on the 16th day of incubation or a test stimulus for which the frequency was offset by 8 Hz in all cases.

The control chicks manifested indifference to both sides and only one chick was found more often in the area of the stimulus having a flash frequency of 10 Hz. Among the chicks irradiated with a 10 Hz [modulation] frequency, the response of approaching the stimulus with the 10 Hz frequency was more sharply expressed than for the 2 Hz stimulus. The occupancy duration in the area of the 10 Hz stimulus for the experimental chicks was 159 s while the number of approaches and contacts amounted to 2.5 and 1.8 respectively. For the controls the values were 93 s, 0.5 and 1.3. The difference between the results for the control and experimental groups was statistically significant with $p = 0.05$. The preference indices for the chicks irradiated during embryogenesis according to all the indicators were 0.7, 0.7 and 0.8 which indicates a preference among the irradiated chicks for the stimulus with a frequency of 10 Hz. Among the experimental chicks a clear preference for the stimulus with a frequency of 10 Hz was observed in 56% of the cases. Among the control chicks a preference for the stimulus with a frequency of 10 Hz was observed for 1 (chick). The difference between the control and experimental groups was statistically significant with a probability of 97.5%.

Analgous results were obtained by irradiating 16 day embryos with EMFs having a modulation frequency of 9 Hz. In five control chicks the average values of the preference indices were 0.4 and 0.54 which attested to the absence of preference to any particular test stimulus. And only in one chick was there observed a preference for a light stimulus with a frequency of 9 Hz.

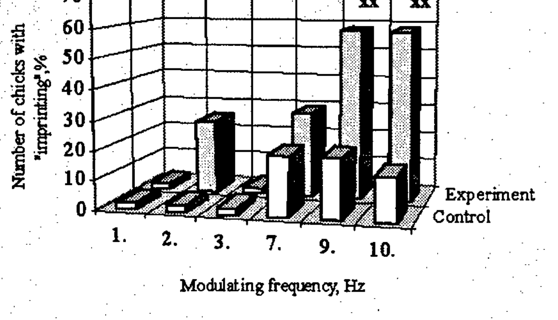
Among nine chicks irradiated during embryogenesis with a frequency of 9 Hz, we observed a different pattern than for the controls. They were found in proximity to the 9 Hz stimulus for a longer duration and were more often in contact with it than the control chicks. From the nine chicks that were irradiated during embryogenesis with a modulation frequency of 9 Hz, five preferred the light stimulus having a frequency of 9 Hz as was indicated by the high stimulus preferences of 0.7 to 1.0 for time in proximity, 0.6 to 1.0 for number of approaches and 1 for contacts.

A different pattern is obtained for the influence of EMFs with modulation frequencies of 7, 3,2 and 1 Hz on 16 day embryos.

Upon presentation of a light stimulus with blink frequencies of 7 and 15 Hz to chicks which were irradiated during embryogenesis with a modulation frequency of 7 Hz, their response could not be distinguished from the response of control chicks. Among five control chicks a clear preference for a light stimulus with a frequency of 7 Hz was only observed for one. The remaining chicks paid hardly any attention to the light stimulus and the indices of preference among them for the time in proximity, number of approaches and contacts were 0.2. Among chicks irradiated during embryogenesis with a 7 Hz modulation the average values of the indices amounted to 0.2, 0.3 and 0.16 which also indicates the absence of any preference for the stimulus with a frequency of 7 Hz. However among three of the ten irradiated chicks we observed a clearly displayed response of approach to a light stimulus with a frequency of 7 Hz (the preference index for them was greater than 0.5).

For irradiation of embryos with EMFs having modulation frequencies of 1 or 3 Hz, all the chicks (both the controls and those irradiated during embryogenesis) showed no preference for these frequencies (Figure 2). For a modulation frequency of 2 Hz the irradiated chicks showed a preference for a 2 Hz stimulus in only 20% of the cases while among the control clucks any preference was totally absent.

Fig. 2 Number of embryos prefering EM modulated signal



Thus the results obtained indicate that the brains of embryos at the 16th day of incubation can fix an electromagnetic stimulus with a modulation of 9 or 10 Hz in the meander regime and retain this information during the subsequent period.

The results obtained suggest the possibility of an influence of EMF modulation on the development of biological effects at the level of the most complicated systemic interactions of organisms. This permits modulated EMFs to be separated into a special group of radiations whose biological effect depends not only on the magnitude of the absorbed energy, but also on the form of the modulation "addressed" to one or another functional system. This permits us to reach the conclusion that in evaluating the hazards of modulated EMFs it is not only the magnitude of the absorbed energy that it important, but even the very fact of human contact with this form of irradiation is important.

The individual characteristics of human beings and their individual susceptibilities to the specific regime of EMF modulation are both of significant importance.

This phenomenon must be taken into account in the development of hygienic standards documents and in EMF theraphy.

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AN EPIDEMIOLOGICAL STUDY ON ELF-EMF AND CHILDHOOD CANCERS IN JAPAN (1999-2001)

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■ INTRODUCTION

A national case-control study on ELF-EMF and childhood leukemia (CL)/brain tumors (CBT) has been implemented since 1999, whose purpose is to survey new 1,000 CL and 500 CBT cases together with their sex, age and residential area-matched controls in Japan, by National Institute for Environmental Studies, as a collaborative center for WHO International EMF Project (1996-2005) in collaboration with National Cancer Center, National Children's Hospital and several medical universities.

■ SUBJECTS AND METHODS

1) Case-control selections

For this study, a central office for survey was opened in National Cancer Center, to which all the newly diagnosed cases in the related major hospitals in Japan were requested to be reported. The study was designed to set 3 controls for each case in the "catchment area", consisted of the Kanto, Kansai, Hokuriku, Hiroshima and Kita-Kyushu areas, where interview survey was applied and 1 control for each case in other areas where studied with mail survey. Ten children were selected for each case from a pool of 120,000 children randomly selected using the Resident Registry records in the randomly selected local governments and three or one "yes" responders have been chosen as controls.

2) Exposure assessments

ELF-EMF levels in child's bed room have been measured for a week with EMDEX-Lite (Etertech Co. Ltd.), while other spot measurements with EMDEX.were also added for major points in each house including living room. Measurements of in-home radon,γ-ray, VOC etc. have also been conducted for the cases of interview survey.

■ INTERIM RESULTS

It is expected a total of about 600 sets of case and control for CL (300 sets for the "catchment area" alone) will have been studied until the end of this fiscal year. Therefore, it is now under consideration whether an extension of the period is necessary or not. The number of those for CBT will be less than 300 even when both of the cases are combined. The details of the study and the possible implications of it will be described.

Summary of Basic Research Subjects on Bioelectromagnetic Issued in China

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Over 50 subjects have been initiated using cell culture, animal, and human models to investigate possible biological effects of exposure to electromagnetic fields (EMF) in China since 1986. Most of them were supported by the National Natural Science Foundation of China (NSFC). Others were supported by the Ministry of Science and Technology (MOST), and The Chinese Academy of Science (CAS).

There were about 24, 11, and 6 subjects issued using cell culture, animal, human models respectively. There were about 11 subjects were related to biological effects on clinic treatment. Fewer subjects were supported by NSFC, MOST, or CAS which were related to epidemiological studies. But some of these kinds subjects were supported by other branches.

There were about 20 universities, 4 institutes, and 2 hospitals included in the conductor institutes.

DEALING WITH RADIOFREQUENCY RADIATION: THE EXPERIENCE IN THE REPUBLIC OF THE PHILIPPINES

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In the Republic of the Philippines, the national government agency in charge of radiation protection from electrical/electronic devices is the Bureau of Health Devices and Technology (BHDT), former name: Radiation Health Service, of the Department of Health.

Radiofrequency radiation (RFR) is one type of radiation falling under the jurisdiction of the BHDT. Prior to 1995, BHDT involvement in RFR had been in testing of microwave ovens. However, since 1995, the BHDT has been involved in various activities pertaining to telecommunication applications of RFR. These include both desktop and on-site evaluation of telecommunication facilities such as cell-sites (mobile phone base stations) and of radio and television stations. BHDT health physicists have also been busy attending public hearings as resource persons and court hearings as expert witness over the past five years. They have also been involved in media coverage of the RFR issue.

The paper gives the details of all these activities and the lessons learned.

Effects of Whole Body Exposure to 50Hz Electromagnetic Fields on the LeukocyteAdhesion in Mice

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■ Objectives

Effects of 50Hz electromagnetic fields(EMF) exposure on leukocyte are mainly performed *in vitro* system, however, little information of these is available *in vivo* experiments. In order to investigate the acute and subchronic exposure effects of 50Hz EMF on leukocyte behavior *in vivo* system, we used a newly-developed dorsal skinfold chamber(DSC) technique and a cranial window(CW) system for measuring the behavior of intra-microvascular leukocytes in the cutaneous and cerebral microcirculation in mice, respectively.

■ Methods

Male mice(BALB/c) having the DSC were subjected to intravital-microscopic study. We have developed the DSC with non-metal materials of Duracon resin, which could not be physically affected by EMF exposure. For visualization of intra-microvascular leukocytes, fluorescent dye(rhodamine 6G; 0.3mg/kg, iv) was injected. The magnetic flux densities used for the acute exposure(30 minutes) were controlled at 3, 10, 30 mT at the center of animal body(n=10 each), respectively. For subchronic exposure study, mice were divided into 2 groups(n=10-12 each), i.e., exposure group with 50 Hz EMF at 3 mT and control group with sham exposure. The 50Hz EMF exposure was intermittently performed everyday from 14:00 to 12:00(22hours/day) for 15 days. The numbers of the leukocyte which rolling or adhering to the venular walls were measured from video images.

Male SCID mice having CW were subjected to evaluate the effects of 50 Hz EMF on leukocyte behavior in the pial microcirculation. Mouse CW is a closed glass window system istalled into the pariental region of the mouse. Concurrent with usual fluorescent microscopy, real time confocal laser fluorescent microscopy was also used for the vital study. For acute exposure study, mice having the CW were divided 2 groups, i.e., exposed group with 50 Hz EMF controlled at 30mT for 30 minutes and control group with sham exposure for 30 minutes. For subchronic exposure study, mice were divided into 2 groups(n=10-12 each), i.e., exposure group with 50 Hz EMF at 3 mT for 20 days and control group with sham exposure. Adherent leukocyte counts to the venular walls were compered between values of before exposure and those of after exposure.

■ Results and Discussion

1. In the cutaneous microcirculation:

Acute Effects: A tendency to increase the adherent cell count of leukocytes due to the 50 Hz EMF exposure toward higher magnetic field intensity was recognized. Following the exposure at 30 mT, the counts of adherent cell was significantly higher than those obtained before exposure($p<0.05$).

Subchronic Effects: Following subchronic exposure to 50Hz EMF, statistically significant increases($p<0.05$) in adherent leukocyte counts were noticed, however, there was no change in IL-1β.plasma levels between before and after exposures in the exposure group. No noticeable changes in the adherent cell counts were observed between before and after sham exposures in the control group.

2. In the cerebral microcirculation

After EMF exposure, adherent leukocyte counts to the venules also tended to increase compared with those of before EMF exposure, however, no statistical changes were recognized in the both acute and subchronic exposure experiments.

■ Conclusion

The results indicated that 50 Hz EMF exposure influence cell to cell interaction between venular endothelial cells and leukocytes. Previous observations using human monocyte in *in vitro* system indicated that changes in cytokine profile of monocyte were induced by exposures of 50 Hz EMF[1-2] may be involved in this phenomenon. Further studies will be required.

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NATIONAL PROGRAM FOR TRAINING IN RISK PERCEPTION, RISK COMMUNICATION AND RISK MANEGEMENT AS A POLICY OF PRECAUTIONARY APPROACH

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■ INTRODUCTION

The process of standard harmonization worldwide in the field of electromagnetic fields (EMF) increase the public concerns of human exposure, new technologies and possible adverse outcomes on human health. Populations in different countries are arguing why their own standard limits are much above than the limits accepted in other countries. In every country there are problems with involving new technologies especially energetic, telecommunication and mobile phones. Most of the problems are in the risk perception area. There are ideas if and how the precautionary approach policy to be included in the standards. Our opinion is that the policy of precautionary approach develops more problems in people's feelings to the risk perception. This is only one of the ways to reach good understanding between scientists, administration and general population about the health risk and risk/benefit evaluation processes.

■ OBJECTIVE

The aim of this study is to present another way for decrease the wide public opposition to the standards developed for new technologies in the field of the EMF human exposure, and to move faster to an international framework for EMF standard development.

■ METHOD

Here we present one way to reach a success in the field of public concerns to the EMF standards harmonization process. We propose a national program for training in the field of risk perception, risk communication and risk management. It covers the whole population – from children and families, to administration and government. Our opinion is that the way to settle the problems between new technology, production, administration and general population is not by using precautionary approaches in standards, and to create a double side communication which will show us in future which is the better way to go ahead.

This national program was presented more detailed as a poster presentation on the Eastern European Meeting in Varna, Bulgaria, in May this year.

One of the main aims of this program is to develop an effective system of public relations on problems dealing with the EM-radiation effects and protection. Another one is to collect information about the public perception of risks from EM-exposure among different population groups.

The auditory to whom the program is directed is the entire society, including:

- population, interested in the possible adverse effects of EM-radiation from various sources in the household and in the environment;
- population groups, showing hypersensitivity to EM effects or aggressive attitude towards expanding the EM-radiation sources;
- employers having an interest in the safety and healthy workplaces and the low level of sickness absenteeism, occupational diseases and injuries;
- workers, wanting to learn more about the risks in workplace and the means to reduce them;
- specialists charged with the control, such as industrial hygienists (from state and private laboratories) controlling by measurement and assessment the adherence of workplace and environment to the hygienic standards;
- specialists in risk assessment and management looking for more information on the hygienic standardization criteria and the methodology for assessing the EM-effects;
- specialists in measurement and assessment, biological effects, hygienic standardization, assessment of EM exposure and risks from EM-radiation;
- occupational safety specialists;
- ecologists and specialists in assessment of environmental impact;
- business managers from institutions, organizations, committees, associations concerned with the assessment of adverse effects of environmental exposure on population health as well as with the legislation;
- media.

Various methods and approaches are planed to be used in order to achieve the above mentioned objectives:

- short press releases, including intelligible scientific information;
- fact sheets to be published in newspapers or available through electronic media;
- development of a set of various popular materials, providing information on the scientific progress concerning the biological effects of EM-radiation and others topics;
- scientific reports in news bulletins, national scientific journals and popular science editions.
- articles to be published in special, branch or technical journals;
- booklets and news sheets designed to the population;

- publishing a periodical and booklets, providing information on the current problems of EM effects and the protection against them;
- making documentaries and distributing videocassettes;
- organizing a center for training different specialists in measurement, assessment of the effects and risks from EMF (in the work and living environment as well as in the everyday life), standardization and protection against EMF;
- popular training courses in biological effects of EMF and protection against them to be carried out in a training centers and universities;
- specialized training courses to be carried out in higher schools as a part of subjects 'ecology', 'medical physics' and 'hygiene' as well as a part of engineering, biological and medical higher education;
- school classes in EM effects;
- local (regional) scientific forums, meetings, discussions and others on regional problems, dealing with the EMF;
- national (summer) schools for the population and experts, national scientific meetings on the EM-effects and others;
- use of electronic media information.

The program covers the 'involuntary' and 'voluntary' exposure to EMF, resulting in different risks. The population perception of risk will be also studied in case of involuntary, voluntary, unfair, non ethical and other risks.
Various communication mechanisms will be used such as: group discussions, publications, press releases, short TV video films, training video materials, cartoons, instructions, advertisement, hot communication lines, wide social forums, competitions for realizing special projects', special festivals, booklets, demonstrative boards and materials, INTERNET and others.

On the Varna meeting there was presented a working program, also, including the concrete activities have to be done by the National Program Committee of the International EMF Project, also by administration, voluntary societies, scientists, experts.

■ CONCLUSION

Here, I want to direct your attention on the possibility to use such a program for developing a new viewpoint in big part of the general population to think more positive on the standard harmonization process.
We think that one of the main possibilities to develop an international framework for standard is to have the support of the every level of the society. Following this way, we can reach better results in the policy for accepting standard limits in our own country, also in other countries in East Europe. In our point of view this way is more flexible to get a result than the way to use the precautionary approach in standards.

DIFFERENT ASPECTS OF ELECTROMAGNETIC HYPERSENSITIVITY

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■ Objectives

Diseases obviously or possibly caused by environmental factors in general like Multiple-Chemical-Sensitivity (MCS)-Syndrome, Idiopathic Environmental Intolerance (IEI) or Chronic-Fatigue-Syndrome (CFS) are an increasing problem of modern industrial societies. Also the group of self-reported electromagnetically hypersensitive persons (E. H.) is growing throughout Europe and several countries world-wide. The electromagnetic fields regarded by these group to be responsible for bodily complaints are often in the very low amplitude range, typically orders of magnitude below the limits. Though interactions of strong electric and magnetic fields with living matter are well-known and authoritative restrictions are based on those interactions, the scientific evidence for the link between weak fields and clinical symptoms remains poor. The spectrum of approaches to the nature of this phenomenon is also broad. Some researchers ask if those phenomena represent a real sensitivity. Others claim a specific pattern of symptoms. A situative reaction or a behaviour caused by the media society we live in is also discussed. Our own research is committed to identify hypothetical causal links between the technically produced electromagnetic fields and sensations, clinical pictures or certain patterns of symptoms like fatigue, concentration failure, sleep disorders etc.

■ Methods

In the past years, we examined about 40 E. H. persons in our laboratory. These persons and healthy volunteers as controls are asked to describe individual subjective symptoms connected with electromagnetic exposure in their everyday life. The social situation, internal and neurological status and behaviour were adequately documented by specialists. In a provocation study, E. H. persons as well as controls were exposed two times (with a short recreation period) to a series of ten field situations. Since medical or psychological questionnaires described in literature normally do not provide sound data concerning special sensitivities, we asked patients and healthy control persons (probands) to guess or even to „feel" in two consecutive sessions whether or not extremely low frequency (ELF) fields were switched on. The 50-Hz-fields were switched on or off at random on a stochastic basis ten times during one session. The probability of fields being activated was 50 %. This method is normally used in sensory physiology in order to detect subliminal sensory excitations. Additionally blood samples were taken for melatonin determination by radio-immunoassay.

■ Results

Results of the up to now approximately 40 experiments do not show significant differences in scores of groups of patients and controls. There were also no detectable correlations between scores and various parameters like patterns of symptoms, environmental factors, social positions and others. Results of narrative interviews insinuate in many cases reactions which are dominated by a special situation and intensified by mass media influences. In order to assess endocrinological parameters in terms of the melatonin hypothesis we determine plasma melatonin levels to find deviations from normal range. Preliminary results do not show significant differences of plasma melatonin levels between groups of patients and healthy controls. This negates the idea of a connection between electromagnetic hypersensitivity and the so-called „low-melatonin-people" which are known in literature.

■ Discussion and Perspective

Critical limitation of hitherto studies on self-reported electromagnetically hypersensitive persons are on the one hand a somewhat improper representation of everyday life field situations possibly leading to the complaints and on the other hand an often uncertain determination of the endpoint in matters of a medically clear diagnosis. These difficulties enable different interpretations and vulnerability of results. For future research we are planning to provide a more complex electromagnetic environment with low and high frequency components, adapted to the situation described by the E.H. persons in order to correspond to the issue of frequency selectivity reported by several persons convinced to suffer from electromagnetic hypersensitivity. The extended study design we are composing should cover also physiological measurements and subjective stated sensations of the persons under test. The aims are provocation of E. H. symptoms for scientific research reasons on the one hand and help to avoid or reduce symptoms to aid these persons on the other hand.

ACKNOWLEDGEMENT: We are indebted to Mrs. F. Gholamrezaei for technical assistance.

THE APPLICABILITY OF CURRENT AND PAST RF BIOLOGICAL RESEARCH TO NEW TECHNOLOGY (3G): PORTABILITY REQUIRES A MECHANISM

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About 300 biological studies have been initiated using various mobile telephony signals. Even though these studies are comprehensive in addressing current technologies they do not and cannot cover the infinite number of possible frequencies and modulations in use. For example, the majority of these studies utilize generic type GSM signals, but by no means cover all the possible GSM modulation characteristics. Although 3G will utilize a combination of current technologies the future may bring additional variations. Is it necessary to test all possible combinations of frequency and modulation to determine whether or not each signal type will or will not cause adverse health effects, or is current research portable to new technologies? The answer to this question depends on the mechanism of interaction of the RF with the biological system.

A thermal mechanism depends only on the amount of energy absorbed and thus its frequency dependence is predictable. The amount of energy absorbed will depend on the electrical properties of the tissue and the geometrical interaction with the biological object, both of which will cause well-established frequency variations. There is no modulation dependence for a thermal mechanism. A non-thermal mechanism, on the other hand, would be expected to exhibit frequency dependent responses, modulation dependent responses or both. The current 300 mobile telephony studies using all technologies test the hypothesis of whether there is a frequency dependent or modulation dependent response. A workshop was held in May 2001 in Washington DC where a group of experts considered the plausibility of various proposed mechanisms (For a summary see the Research section at http://www.mmfai.org/). This group concluded in part, "For exposures to RF energy from sources in the general environment and from use of mobile telephone devices, the only clearly plausible mechanisms for RF interactions with biological systems involve heating." This workshop evaluated physical mechanisms of interaction from a theoretical basis only. Subjects considered included: temporal and spatial temperature gradients, alteration of membrane potential, membrane rectification, polarization of structures or molecules, RF pumping and chemical kinetics, magnetic dipole interactions, coherence and cooperative interactions. None, except for thermal gradients, were considered plausible at environmental exposure levels but most required further theoretical evaluation to determine their limitations.

Theoretical examination of proposed mechanisms is one approach that is necessary. A second approach to a determination of possible mechanisms is to study a repeatable biological effect and establish the biochemical and biophysical event that causes this response. An examination of the RF biological effects literature does not provide a consistent body of data that can be used as the basis for formulating theoretical postulates other than a thermal mechanism. There are a number of publications that report effects at non-thermal levels. These reported findings do not build a consistent or connected body of data and thus do not support one another. Support must come from either independent replication or from established biological or biochemical connections in which the occurrence of one finding would predict the second. Science builds upon the mechanistic knowledge gained in one experiment by using it to generate the hypotheses for another experiment. No reported "non-thermal" experimental RF biological effect has been able to be repeated in independent laboratories and connections have not been established between reported findings. In the absence of any plausible mechanism to explain reported non-thermal "positive" findings and in the absence of any consistent or repeatable biological results one must conclude that the only acceptable mechanism is thermal.

■ Conclusions

To determine whether current experimental findings are applicable to all current and proposed (3G) technologies one must understand the basic physical mechanism that is causing any biological response. At the present stage of RF research, only studies in two main areas, the thermal effects of RF energy and neurostimulation by RF fields and currents, have been established. Theoretical analysis does not provide current support for non-thermal effects. No experimental model has been developed which provides a repeatable non-thermal response. Without such a repeatable response the systematic pursuit of any non-thermal mechanism is not realistic. The lack of evidence or any real indication of a non-thermal mechanism leads one to conclude that current thermally base standards are sound and thus all current research findings are portable to all current and new technologies.

EMF – Related Activities in Thailand

Nisakorn Manatrakul [1], Sawat Pranom [2], Siriwat Wasoontarajaroen [3] and Surasak Parisanyakul [1]

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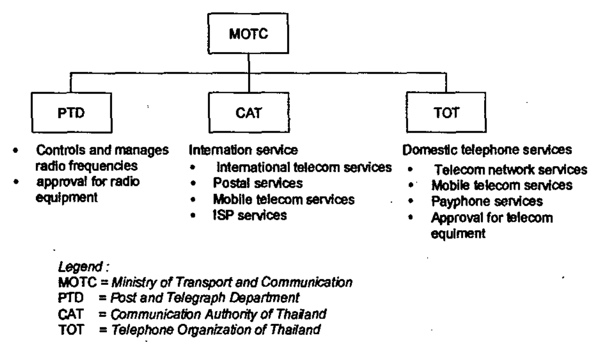
A number of organizations in Thailand deal with devices that emit electromagnetic fields (EMFs). These include:

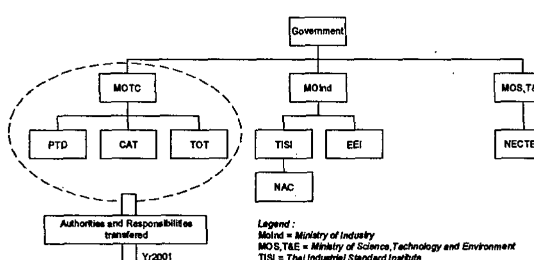
1. The Thai Industrial Standards Institute (TISI)
2. The Post and Telegraph Department (PTD)
3. The Communications Authority of Thailand (CAT)
4. The Telephone Organization of Thailand (TOT)

The following diagrams outline the responsibilities of some of these organizations and show their affiliations within the government.

1.The Current Situation.(Yr.2000)



2.Telecommunications Standardization Bodies and Testing Labs



At present, there is no organization directly working on EMF biological effects and regulation control.The Department of Medical Sciences (DMSc), Ministry of Public Health (MOPH), is responsible for the development of guidelines for safe use of radiation and medical devices. The Division of Radiation and Medical Devices (DRMD) of DMSc periodically inspects microwave ovens for the purpose of consumer protection. Part of the inspection includes measuring radiation leakage from microwave ovens and comparing the outcome with guidelines issued by other countries.

The leakage radiation from used microwave ovens have been investigated and reported by Parisanyakul S. et al. (100 used microwave oven from 25 manufacturers)(1) and Wasoontarajaroen S. et al. (125 used microwave ovens from 31 manufacturers)(2). In these reports, the results showed that none of the oven models evaluated were found to emit radiation in excess of the maximum allowed leakage specified in the regulations of a number of foreign countries. Microwave leakage measurements showed that the adverse health effects are not expected to occur as a result of radiation exposure during cooking with these microwave ovens. Magnetic field measurements were found to be below the majority of exposure guidelines recommended by a number of foreign countries and international organizations. There is to date no conclusive scientific evidence that power frequency magnetic fields at these levels are harmful to human health.

In the area of electromagnetic compatibility (EMC), there are two testing laboratories in Thailand – one of them is operated by the Electrical and Electronic Products Testing Center (PTEC) and the other by the Electrical and Electronics Institute (EEI). These laboratories provide services to the electronics industry.

In conclusion, Thailand does not have any regulations or guidelines for protection of the general public from EMF exposures. There exists an urgent need to develop such national guidelines for promotion of the safe use of EMF emitting devices and for subsequent health risk assessments.

■ References

(1) Parisanyakul S., Akavakorn V. and Sakwised N.: Leakage Radiation from Microwave Ovens.
(2) Wasoontajareon S., Thansandote A. and Pongpat P.: Microwave Leakage and Power-Frequency Magnetic Fields from Microwave Ovens.

More information can be found on web sites:
www.ptd.go.th; www.cat.or.th; www.tot.or.th

MOVIE ON THE HEALTH EFFECTS OF THE CELLULAR PHONE & BASE STATION

Femme-Michele Wagenaar

Not Available

FMK SCIENCE HELP DESK

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Sciencefaqs, **a living library for health spokespersons**, from industry, research institutes, health authorities and governments, offers a way to understand, summarise and keep up to date with ongoing international research and guidelines about health effects related to the use of mobile phones and base sites.

The science help desk features **eight divisions of information**: a members dialogue, abstracts, bioeffects, position statements, standards, weblinks, the WHO EMF Project studies data base and the worldwide funding agencies.

We have the support and contributions of the science authors doing the relevant research. Also we have the support of the Chair on the International Commission of Non-Ionizing Radiation (ICNIRP) Dr. Alastair McKinlay, IEEE Operations Publications Professor Bill Hagen, the Bioelectromagnetics Society Past President Professor Frank Barnes, the Secretary General of the Union of Radio Sciences International (URSI) Professor Paul Lagasse and the Outgoing Chair of the W.H.O. EMF Project, Mike Repacholi.

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Forum Mobilkommunikation (FMK) is a Non-Profit industry association in Austria sponsoring sciencefaqs by providing the operating costs of http://sciencefaqs.com. FMK provides for its own health spokespersons as well as for any paid subscribers the opportunity to be better informed and up-to-date about the research on mobile telecommunications and health.

There are presently 400+ abstracts from papers on mobile phones and health incorporated into the web **Abstracts' library** of the SHD. Accompanying very important abstracts are **Q& As** about whether the research follows the required WHO research criteria, and about the weight of scientific evidence in this area.

All the 942 reference titles of the **Zmirou French Expert Report**, Jan 2001, have been added to the abstracts files recently. An English translation of the science review of the Zmirou Report has been placed in the Bulletin Board.

Bioeffects, summarises and explains the human health topics of possible concern from telecommunications' exposures: cancer, genotoxic effects, central nervous system effects, thermal effects, anecdotal effects and interference on medical devices. Recent experts' published reviews give the weight of scientific evidence on each topic to date.

A world atlas of **Standards** tables keeps spokespersons up to date on guidelines, and the **Bulletin Board** includes eminent scientists' speeches and summarizes and explains current health topics.

There are two areas where subscribers can make statements and ask questions, and give feedback called the **Forum** and **Special Issues Science**.

Hot issues keeps you up to date on recent issues.

There are two files from the **WHO EMF Project database** made user-friendly, the EMF Studies and the EMF Funding Agencies.

The sciencefaqs.com team update **Sciencefaqs daily** with hot issues, new papers, recent conference proceedings, weblinks, new exposure guidelines, expert reports, and current issues on health related to telecommunications

This special **non-profit** web science helpdesk is limited by password, and subscription. For **free 24-hour access** and/or information on yearly subscriptions email Melanie Stelzer (stelzer@feei.at) your details (name, position, company, address, fax, phone & email) for a user name & password.

THE PURPOSE OF WHO'S EMF STANDARDS HARMONIZATION PROJECT

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■ Abstract

In November 1998, WHO commenced a process aimed at the harmonization of EMF standards worldwide. As over 45 countries and 8 international organizations are involved in the International EMF Project, it provides a convenient umbrella and a unique opportunity to bring countries together to develop an agreeable framework for standards. This framework can then be used to better define exposure limits once the EMF Project has completed its assessment of health risks associated with EMF exposure. With active participation by national authorities in the process of assessing health risk and the development of a standards framework, they will feel committed to a harmonized process for standards.

This WHO initiative to provide a framework for harmonizing EMF standards is a response to the fact that many countries are considering new EMF standards. Globalization of trade and the rapid introduction of mobile telecommunications worldwide have focused attention on the large differences existing in standards. Differences in the EMF limit values in standards in some Eastern European and Western countries are, in some cases, over 100 times. This has raised concerns about their safety and has led to public anxiety about increasing EMF exposures from the introduction of new technologies.

It will take some years before this activity is complete, but the process will be finalized at the same time as the formal assessment of EMF health risk assessments are published by WHO and IARC. Thus, the next generation of standards would be able to incorporate this health risk assessment information within the same harmonized standards framework.

This paper describes the aims and objectives of the harmonization process, progress made so far, the schedule and future activities for completion of the framework.

■ Introduction

In November 1998, WHO commenced a process of harmonization of electromagnetic fields (EMF) standards worldwide. Over 45 countries and 8 international organizations are involved in the International EMF Project. Thus the Project provides a unique opportunity to bring countries together in a logical process to better define any health risks associated with EMF exposure and to encourage the development of harmonized exposure limits and other control measures that provide the same level of health protection to all people.

This WHO initiative to harmonize EMF standards is a response to the fact that many countries from the former Soviet Union and elsewhere are now considering new EMF standards. Globalization of trade and the rapid introduction of mobile telecommunications worldwide, have focused attention on the large differences existing in standards limiting exposure to EMF. Differences in the EMF exposure limit values in standards in some Eastern European and Western countries are, in some cases, over 100 times. This has raised concerns about their safety and has led to public anxiety about increasing EMF exposures from the introduction of new technologies.

It will take some years before this activity is complete, but it is hoped that the process will be finalised before the formal assessment of EMF health risk assessments by WHO and the International Agency for Research on Cancer (IARC). Thus the next generation of standards would be able to incorporate this health risk assessment information within the same harmonized standards framework.

■ Benefits of Harmonized International EMF Standards

Since much recent technology uses various parts of the electromagnetic spectrum, there are many benefits to having harmonized standards for EMF exposure. These are listed below.

- Increased public confidence that governments and scientists agree on health risks
- Reduced debate and fears about EMF
- Everyone protected to the same high level
- Economic benefits to trade which result in better health care

■ Elements of Harmonized Framework

In establishing the framework for harmonization of EMF standards, numerous questions will have to be addressed. For example:

- Criteria to be used to evaluate research results
- Detailed requirements for a scientific rationale to support limits
- Model for developing standards
- Methods for determining compliance
- What to do with isolated data points at specific frequencies
- When research data are absent in particular frequency ranges, how and with what degree of confidence can results be extrapolated to other frequencies or intensities
- Applicability and extrapolation of animal or cellular studies to humans

- Should one standard cover the whole frequency range from 0 to 300 GHz
- Safety factors: should they address scientific uncertainties in the fundamental research or imprecision in the techniques used for exposure assessment and should they also allow for gaps in knowledge?
- Should standards be one or two tiered - i.e. differentiate between occupational or controlled exposure and general population or uncontrolled exposure
- What about social and economic impacts; should they be considered
- Should they be in a form that methods for determining compliance are made easier

These and many other questions need to be addressed through the standards harmonization process.

■ Activities to Date

Before the launch of the EMF standards harmonization project, WHO organized an international meeting in conjunction with Russian authorities to discuss scientific results of studies published in Russian and not easily available to non-Russian speaking countries. In addition, a large part of the meeting was devoted to understanding the criteria used to evaluate the science for the Russian EMF standards and the procedures used to establish exposure limits. Russian scientists also heard about criteria for acceptance of scientific reports and the rationale for standards established by ICNIRP and the US Institute for Electrical and Electronic Engineers (IEEE) C-95.1 Committee. This was an extremely valuable experience that has lead to Russian scientists participating actively in the standards harmonization process. Similar meetings have now been held in China. The WHO initiative for harmonizing EMF standards world wide was formally launched at a press conference and the first meeting in Zagreb, Croatia in November 1998. Over 21 countries were represented in the initial meeting to identify a process: Australia, Austria, Canada, Croatia, Czech Republic, Finland, France, Germany, Hungary, India, Italy, Japan, Netherlands, New Zealand, Poland, Russian Federation, Slovenia, Sweden, Switzerland, United Kingdom, United States of America. At this meeting each country provided details of their current standards or at least what was being used as informal guidance and what was intended in the future. Annual project and country meetings will be held to encourage standards harmonisation. Regional meetings have been organized that will allow scientists in these regions to input their ideas to the standards framework. This will be formalised into a framework for EMF standards that will be subject to an international meeting in Geneva.

■ Strategy for Harmonization

Objective: The purpose of this activity is work towards, and hopefully achieve, international agreement on a framework for developing guidelines on protection of the public and workers from exposure to EMF. EMF is defined as electromagnetic fields in the frequency range 0 to 300 GHz.

Components of the Framework: Components that address the framework are:
- Standard concepts and terminology
- Criteria used to evaluate research results for standards development.
- Requirements for a scientific rationale to support limits.
- Model for developing standards.
- Methods for determining compliance.
- How to evaluate inconsistencies and gaps in the evidence
- When research data are absent in particular frequency ranges, how and with what degree of confidence can results be extrapolated to other frequencies or intensities?
- How should precautionary approaches be considered if needed?

Workplan: Development of the framework will be carried out by working groups formed to address the key components listed above. Working group meetings will be held, generally in conjunction with scientific meetings in key geographical regions that will allow the input of scientists and government officials in those regions.

One goal of setting up the working groups is to enhance the quality of communication among scientists and government officials, in examining the scientific basis for the standards and the assumptions that underlie them. Working groups will be formed to address the following topics:

WG1: Standard concepts and terminology

WG2: Criteria used to evaluate research results for standards development. Requirements for a scientific rationale to support limits, and a comparative analysis of the different scientific rationales for various standards.

WG3: Model for developing standards. Safety factors: how should they address scientific uncertainties in the research database and imprecision in the techniques used for exposure assessment?

WG4: Should social and economic impacts be considered? How should precautionary approaches be devised if needed?

Draft papers that address components listed above will be prepared and presented to the working groups as a basis for discussion. Working groups will discuss their topics thoroughly and draft recommendations in their report. Drafts will be circulated for comment for approval by representatives of all countries involved in the standards harmonization process.

Schedule of work: The first phase of the work will be by the formation of ad hoc working groups at scientific meetings held in key geographical regions around the

world. A schedule of scientific meetings has been tentatively arranged as shown below. Further details will be given on the WHO EMF Project web page at: www.who.int/emf/

Scientific conferences organized to include working group meetings in key regions.

- ♦ 2nd International EMF Seminar in China: Electromagnetic Fields and Biological Effects: Xi'an, China 23-26 October 2000.
- ♦ WHO EMF Standards Harmonization Meeting: Brooks Airforce Base, San Antonio, Texas 13-14 November 2000.
- ♦ WHO/Peru Government regional seminar: Bioeffects and EMF Standards Harmonization, Lima, Peru 7-9 March 2001.
- ♦ WHO EMF Biological Effects and Standards Harmonization East European regional meeting Varna, Bulgaria 30 April - 4 May 2001.
- ♦ WHO EMF Biological Effects and Standards Harmonization Asian and Oceana regional meeting, Seoul, South Korea 22-24 October 2001.
- ♦ WHO EMF Biological Effects and Standards Harmonization African regional meeting, Cape Town, South Africa 3-7 December 2001.
- ♦ WHO EMF Biological Effects and Standards Harmonization, Moscow, September 2002
- ♦ WHO EMF Standards Harmonization working group China, October 2002

■ ICNIRP Guidelines

The Council of the European Commission has adopted the ICNIRP guidelines on exposure limits. Many countries have adopted or are in the process of adoption of the ICNIRP guidelines. Other countries preparing for or aspiring to membership of the European Union will be considering the ICNIRP guidelines. It is reasonable that the ICNIRP Guidelines be used as a basis for drafting an internationally acceptable framework for standards.

■ Further information

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Further details are available on the WHO EMF Project home page: http://www.who.ch/emf/

■ Further Reading

- ICNIRP (1998) Guidelines on limits of exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). International Commission on Non-Ionizing Radiation Protection. Health Physics 74: 494-522.
- Press release WHO/88: WHO launches an initiative to harmonize electromagnetic field standards worldwide. WHO 17 November 1998.
- Progress Report (1997-1998), International EMF Project, WHO/EHG/98.18, 1998.
- Draft minutes of meeting held in Zagreb to launch the EMF standards harmonization initiative.

Poster Presentation

FDTD CALCULATION OF SAR FOR THE MONOPOLE ANTENNA ON THE CONDUCTING BOX WITH THE METALLIC FOLDER

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■ Abstract

This paper presents the numerically simulated specific absorption rate (SAR) within the human head due to cellular telephones. The frequency considered was 825 MHz and the time averaged radiated power of 0.6 W was used. The influence of the geometrical change of folder length and the connection position between folder and body on SAR for the homogeneous head model has been analyzed.

■ Summary

Today's mobile phones require proof of compliance to standard limits of the specific absorption rate (SAR), before they can be allowed onto the market, SAR is a calculation of the power absorbed by tissue, averaged over a mass, resulting from the radiation of the handset. Thus the estimation of SAR distributions in a human-head tissue while using cellular telephones has become a matter of great concern. Investigation of this antenna-tissue interaction can be performed through accurate solution methodologies such as the finite-difference time-domain (FDTD) electromagnetic simulation approach. Many studies have been performed in the past for calculating the power absorbed in a human tissue exposed to the electromagnetic field emitted by radio-communication equipment. In this paper we extend the previous analyses of parameters that influence the interaction between the antennas and the user's body. This paper reports on results from investigations on the change of SAR by the metallic folder. The FDTD method is used in these investigations.

Our study is for giving guidelines to design the handset getting low SAR value on test state. So the head model considered in this study has been obtained from the real measurement system (DASY3). The simple folder structure was used in this paper for pre-checking a tendency of SAR value by parameters of folder type phones. To simulate the whip antenna straight, the phantom has been rotated 65 degrees to match the reference plane with yz-plane, 40 degrees in yz-plane by x-axis. In folder connecting case, the metallic folder was connected with the metallic body by 1 PEC cell at the connection position.

In the AMPS band, the non-metallic folder or the metallic folder unconnected with the body has little influence on the SAR. In connecting case, the connection position comes to be critical parameter as the length of metallic part.

Decreased survival for childhood leukaemia in proximity to TV towers

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■ Abstract

Objective. In a previous study we reported an increased risk of childhood leukaemia in municipalities proximate to TV towers in north Sydney compared with more distant ones (Hocking B Gordon I Hatfield G Grain H. Cancer incidence and proximity to TV towers Med J Aust 1996; 165: 601-605). The rate ratio for incidence, comparing the inner ring of municipalities to the outer ring, was 1.55 (95% confidence interval 1.00 – 2.41) and for mortality the rate ratio was 2.74 (95% confidence interval 1.42 – 5.27). The objective of the current study was to analyse the survival experience of the cases in detail, to determine whether there are differences between the two populations.

Design and Outcome Measures. Survival data on cases diagnosed from 1972-93 were analysed. Data on all cases who survived for less than one month were verified by the NSW cancer registry and one case diagnosed at autopsy excluded. Data were described by Kaplan-Meier curves. The log-rank and Wilcoxon tests were used to compare the two groups. Cox's proportional hazards model was used to adjust for confounders.

Results. There were 123 diagnosed cases of acute lymphatic leukaemia (ICD-9 204.0) of which 29 (16 deaths) were in the inner ring of municipalities and 94 (34 deaths) were in the outer ring. We found a significant difference in survival (log rank: $P = 0.03$; Wilcoxon: $P = 0.05$). The 5 year survival in the inner ring of municipalities was 55% and in the outer ring 71% (inner 23% worse); at 10 years the survival was 33% and 62% respectively (inner 47% worse). After adjustment for the potential confounders using Cox's model, the mortality rate ratio comparing the inner ring with the outer ring was found to be 2.1 (95% confidence interval: 1.1 – 4.0). We were not able to control for cytogenetic abnormalities.

Conclusion . There was an association between proximity to the TV towers and decreased survival, among cases of childhood leukaemia.

THE INDIRECT EFFECT OF SMF ON SPERM FUNCTIONAL ACTIVITY

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■ Introduction

The technical progress is accompanied by rapidly growing and artificially introduced environmental factors, the direct effects of which are difficult to assess instantly. It is well known that sperm is one of the most sensitive cells in the organism for the effect of chemical and physical stress factors[1]. However, long-lasting exposure of these cells can cause diverse disorders in the organism, especially in its reproductive function. That's why it is important to study the effect of weak physical factors, like SMF, EMF, microvibration, noise, etc., on sperm functional activity. The other thing is that though the cryoscopy of sperm is widely applied in medicine and agriculture, it decreases sperm effectivity as the lipid composition in sperm membrane changes and sperm motility decreases irreversibly[2]. Thus, the subject of the investigation was to find out whether SMF treated physiological solution has modulation effect on bull sperm functional activity and to check whether this effect can be used for effective modulation of sperm functional activity for recovering and increasing its motility, as well as prolonging its life after the cryoscopy.

■ Observations

The experiments were performed on the preliminary frozen bull sperm conserved by liquid N_2 at the temperature of -196°C. Before starting the experiments the sperm was incubated in 2.8% sodium citrate solution. The effect of SMF on sperm hydration (head diameter) and motility was studied using the incubation medium preliminary treated by 0.3T SMF for 30 minutes. 38-40°C temperature was maintained during all the observations. Sperm motility and hydration was estimated during 140 min every 20 min by means of specially developed setup consisting of a biological microscope combined with videorecorder - computer system. The results were compared with the sperm functional activity incubated in untreated physiological (control) solution. It was observed that in the case of sperm incubation in non-treated physiological solution at room temperature its motility gradually slows during 3,5 hours. The latter is accompanied by the increase of sperm hyperhydration. While, the motility of sperm incubated in preliminary 0.3T SMF treated physiological solution at the same conditions was inhibited only by 5%, which was accompanied by insignificant changes in its hydration.

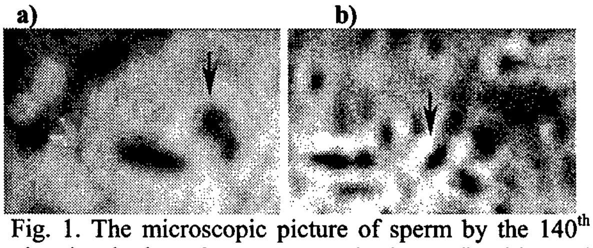

Fig. 1. The microscopic picture of sperm by the 140th min incubation in non-treated (control) (a) and magnetized (b) physiological solutions.

Each columns in Fig. 2 represent the mean values of the motility of 200 sperms in non exposed (control) and 0,3T SMF exposed physiological solutions. The mean value, standard deviation were calculated and the statistical probability was determined by Student-t test with the help of computer program Jandel (Sigma Plot).

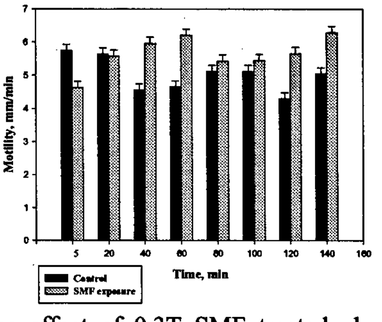

Fig. 2. The effect of 0.3T SMF treated physiological solution on sperm motility.

The first pair of columns shows the sperm motility recorded on the 5th minute after 30min sperm preincubation in control and magnetized physiological solutions. The data show that during the first 20 minutes the sperm motility in SMF-treated physiological solution is lower compared with the control, while during the rest of the time it is higher in comparison with control.

■ Conclusions

The obtained data are interpreted from the point of the correlation between sperm hydration and its functional activity, as well as by the high sensitivity of sperm to SMF. The results allow us to conclude that SMF has indirect effect on sperm functional activity mediated by the structural changing of extracellular water.

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Wideband Antenna for Measuring Human Radiometric Signals

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■ Introduction

Microwave radiometry, as a non-invasive technique which don't pierce inside human and can measure the temperature, is to diagnose early the disease or abnormality by detecting the temperature inside human. It is accompanied with the increase or decrease of temperature in tissue arisen from a disease or abnormality, and as temperature changes, radiated microwaves also change.

So if we model the transfer characteristic of microwave inside human body as measuring the microwave radiated from human surface, we can estimate the temperature inside human body. The frequency range for radiometry is 1 ~ 5 GHz and we use a non-invasive method. Microwave power radiated by the human body is detected by using a direct contact-type microwave antenna. By diagnosing patient's disease at early stage, it enhances more the treatment rate and is very effective method that is able to release the patient's pain and reduce expense.

Because this antenna is contacted to human body, it has very high efficiency and smaller size than the general communication antenna. Numerical approach of design theory is different from that of the general antenna. Because antenna with the wideband characteristic can measure the various frequency ranges, it is possible to detect more exactly the position and size of region having the disease.

■ Antenna configuration

Fig. 1 shows the dipole-type antenna connected to the breast tissue. The designed antenna that has structure of loop-type dipole antenna is deformed from general dipole antenna. We analyzed antenna by using FIM (Finite Integration Method) algorithm. We used an input pulse as a Gaussian pulse and the input impedance of coaxial cable is 50Ω.

■ Results

In fig. 2, the simulation and measurement magnitudes of return loss [dB] are compared with each other. The simulated bandwidth based on 10 dB is about 125% (0.65 GHz ~ 2.82 GHz) and the measured one is about 130% (0.8 GHz ~ 3.8 GHz). It may be noted that the structure is well matched to breast tissue in a broad range of frequencies. This is sufficient as the sensitivity of a multispectral radiometer antenna. The simulated result shows a little difference from the measured result, which may be attributed to the difference of simulation data and real data of breast tissue.

■ Conclusion

In this paper, we suggested a dipole-type antenna for measuring human radiometric signals having a small size and ultra wideband characteristic. To have a small size and wideband characteristic, we designed a circular loop-type dipole antenna.

The designed antenna that gets wideband bandwidth as a result of measurement is suitable for measuring human radiometric signals. If we consider other tissue layers such as a skin, fat, and muscle, we will expect better results.

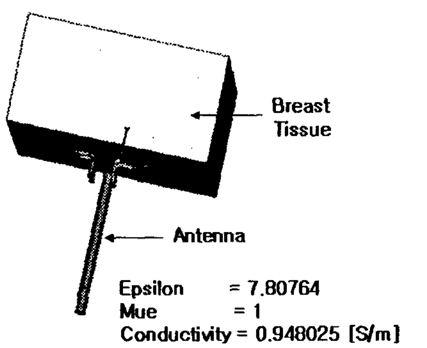

Fig. 1. Dipole-type antenna structure contacting breast tissue.

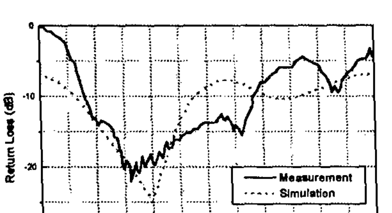

Fig. 2. Comparison of simulated and measured results.

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CANCER INCIDENCE IN VICINITY OF KOREA AM RADIO TRANSMITTERS

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■ Introduction

Several studies have raised the possibility that exposures to electrical and/or magnetic fields may be harmful in particular as a promotion or initiation of cancer. The purpose of this study is to investigate an association between residing near radio transmitters and carcinogenic appearance in Korea based on a geographical correlation design.

■ Methods

Total 42 AM radio transmitters(high power(100-1500kW) 11 site and low power(1-50kW) 31 sites) were investigated. Korean Medical Insurance data(between 1993 and 1996), Population Census data(in 1995) and Resident Register data(in 1995) were used. The exposed area were defined within 2 km from the towers. Four control regions according to each high power transmitters were selected, which had similar populations in the same province(Do) and no towers nearby. The incidences of total cancer, all type of leukemia, malignant lymphoma, brain tumor and breast cancer between the high and low powered area and the control area were compared. The indirect standardized observed/expected ratios were calculated for all transmitters separately and for 4 grouped transmitter defined by their electric powers. bottom margin of 25mm as shown in Fig. 1. It is imperative that nothing appears on a page outside of these margins.

■ Results

There were no significant increase of adjusted incidences by electric power. Among 11 high powered areas, 2 area for leukemia and one area for brain tumor and breast cancer were showed significantly high observed cases.

■ Conclusion

This study design is considered exploratory and not used for determining causality. It needs more detailed exposure assesment and analytical study.

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A SCTL CELL TO CALIBRATE ELECTRIC PROBE IN AIR

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■ INTRODUCTION

A small straight coupled transmission line (SCTL) cell to calibrate electric field probe in air is presented in this paper. Though the SCTL cell [1] can not provide an additional electric field polarization in the transverse section such as the TTEM cell [2] and 6P-TEM cell [3], it can provide high power usability for generating standard EM fields and high field uniformity. We can solve the higher order mode cutoff frequencies in the SCTL cell by the Galerkin method (GM) and obtain the resonant frequencies. The SCTL cell is designed by using the Newton Raphson method (NRM) mixed with the moment method (MM). Measured electric fields and higher order mode resonant frequencies inside the designed SCTL cell agree well with the calculated results by the MM and by the GM, respectively.

■ DESIGNED RESULT

The SCTL cell consists of a rectangular outer conductor tapered at both ends and two straight inner conductors located inside the cell. Each straight inner conductor is connected to the inner conductor of a 50Ω coaxial connector. The feeding method of the SCTL cell is similar to that of X-TEM cell, out of phase [4]. Fig. 1 shows a photograph of a SCTL cell so designed. The input VSWRs of the designed SCTL cell were measured at frequencies from 0.3 MHz to 2000 MHz. We can see that the VSWR at input port is less than 1.1 for the frequencies up to 1190 MHz, the resonant frequency. Useful frequency windows between resonant frequencies are seen clearly. We can that the impedance matching is good not only up to 1190 MHz. Fig. 2 shows that the measured electric field strengths at 12 test points inside the uniform area are quite uniform from 100 MHz to 1000 MHz. Those data were obtained with an isotropic electric field probe (DASY ET3DV5R) when the input power P1 was kept at the constant value of 7dBm. It is shown that the measured electric field distribution inside the cell has maintained high field uniformity up to the first resonant frequency (928 MHz from Fig. 2). The field uniformity satisfies the requirements of IEC1000-4-3 and ISO /TC22 /SC3 not only up to first cutoff frequency but also in the frequency window between the first resonant frequency and the second resonant frequency.

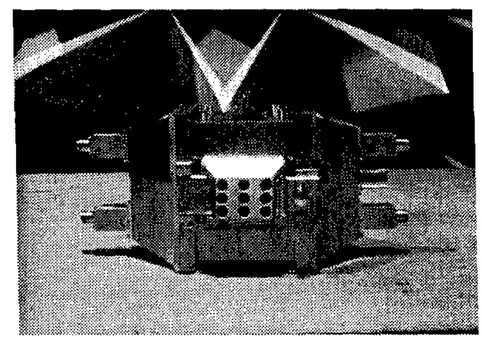

Fig. 1 The photograph of the designed small SCTL cell

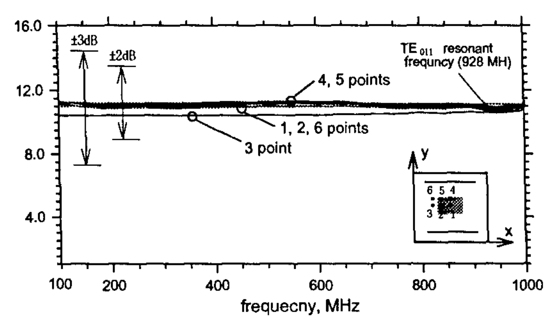

Fig.2. Measured electric fields inside the designed SCTL cell (P1 = 7dBm)

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The Biological Effects Induced by Continual Exposure to 60 Hz Electromagnetic Fields in Mice

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■ Introduction

It is rare studied what is the health effects of electromagnetic fields (EMF) of extremely-low-frequency (ELF) when mammalian is exposured to the fields for a life span or through generations. Some experimental studies indicate that EMF might affect embryonic fetal development and cancer, but the results are inconclusive [1-6]. We studied the effect on mice continuously exposed to 60 Hz EMF from first to third generation.

■ Methods

The test animals were BALB/c mice aged 5 weeks, which were adapted at the specialized breeding cages for 1 week. Each group was continuously exposed to 60 Hz EMF of 5 kV/m, 30 kV/m, 0.5 mT, 1.5 mT from 6 weeks old. After 20-22 weeks old, each mouse with same condition was mated under exposure. And then it was continuously exposed with same conditions. The mice of second and third generation were continuously exposed from pregnant to death with same conditions as parents. The mouse of each generation was studied with careful observation and hematological and biochemical tests. The mice of first, second and third generation were sacrified and studied histopathologically at serious illness or at the age of 46, 66 and 49 weeks, respectively.

■ Results

In the second generation fetus, early fetal death, late fetal death and congenital defects including excencephaly, congenital heart anomaly, etc. were found with 2-4 fold higher frequency in the exposure groups than control. In the mice of exposure groups, the size of testis and ovary decresed. But that of third generation didn't decrease. Lymphoma, adenocarcinoma, squamous papilloma, basal cell epithelioma and adenoma were found at 30 kV/m, 0.5 mT and 1.5 mT in mice of first and second generation. But tumor was not found in third generation.

■ Conclusion

The abnormality rate of exposed group fetus was higher 2-4 times than control group, so EMFs has possibility of influence to fetus development. There is possibility that 0.5 mT induces early death and 1.5 mT and 30 kV/m induce late death and various congenital anomaly. Many benign tumor happened in female mice long term exposed in electromagnetic fields, and malignant tumor happened in male mice. Something wrong views are at first and second generation mainly, and decrese preferably in third generation. For the numerical value of real safety limit at EMF exposure, it is necessary for the various research to confirm living body effect of long term expose

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DEVELOPMENT OF EXPOSURE SYSTEMS FOR ANIMAL EXPERIMENTS IN JAPAN

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■ Introduction

Possible health effects of exposure to electromagnetic field (EMF) have become a great concern of the general public. Therefore, many animal experiments have been conducted. For the animal experiments, not only the precise exposure assessment, especially the local specific absorption rate (SAR) in the test animals, but also the development of desirable exposure system is necessary.

We summarized exposure systems developed for animal experiments in Japan.

■ Liver exposure system

This exposure system was developed to test possible promoting effects of 900 and 1500 MHz digital cellular phones on rat liver carcinogenesis (Fig.1). Rats were constrained with plastic tube and exposed to EMF generated by 1/4 wavelength monopole antenna.

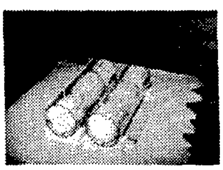

Fig.1 Liver exposure system

■ Head exposure system

This is an exposure system to expose EMF to rat head (Fig.2). Rats were fixed in a plastic tube and located like a carousel. In this exposure system, 10 rats were exposed simultaneously to EMF of 1.5 GHz generated by 1/4 wavelength monopole antenna.

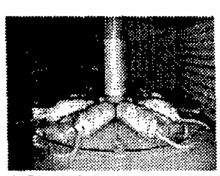

Fig.2 Head exposure system

■ Head exposure system for long-term and large-scale study

This exposure system was developed for a long-term and large-scale animal experiment to test the possible effects of digital cellular phone on brain tumor of rat (Fig.3). 10 rats were exposed simultaneously to EMF of 1.5 GHz. Antenna was placed on the ceiling to localize the exposure within the brain. Because rats change their weight and size during long-term experiment, rats were constrained with 6 types of plastic tube according to their size.

Fig.3 Exposure system for long-term and large-scale study

■ Head exposure system with loop antenna

To simulate the possible effects by EMF from cellular phones, the energy absorption has to be more focused within the head. A small loop antenna was developed to generate localized EMF of 1.5 GHz (Fig.4). In this system, a rat with a cranial window was employed to observe microcirculations with the rat alive.

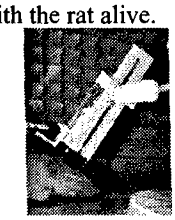

Fig.4 Head exposure system with loop antenna

■ Skin exposure system with short antenna

This exposure system was developed to test possible promoting effects of 1.5 GHz digital cellular phones on mouse skin carcinogenesis (Fig.5). An electrically short monopole antenna with capacitive-loading for highly localized exposure and transparent absorber to allow real-time observation of both the exposure process as well as mouse activities during the exposure were employed.

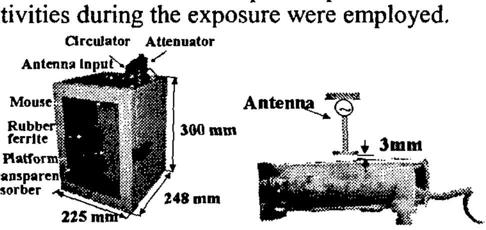

Fig.5 Skin exposure system with short antenna

■ Head exposure system with short antenna

This exposure system was developed for localized exposure within mouse brain. The low whole-body averaged SAR was realized by using a flexible magnetic sheet attachment to the mouse holder.

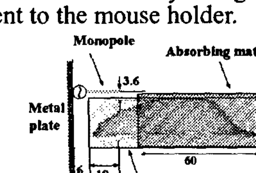

Fig.6 Head exposure system with short antenna

■ Eye exposure system

This system was developed for animal eye experiment (Fig.7). Rabbit eye were exposed to MW from a small coaxial and wave-guide adapter filled with a dielectric material whose relative permittivity was 6.

Fig.7 Eye exposure system

SAR VARIATIONS BY EMI CONDITION OF CELLULAR PHONE CASE

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■ Introduction

In recent years, the cellular phones have been used widely, and also public concern about the EMF safety has grown. The U.S. Federal Communications Commission (FCC) has recently required new specific absorption rate (SAR) evaluation of cellular phones prior to equipment authorization[1]. The typical SAR limits of human head are 1.6 W/kg averaged over 1 g and 2.0 W/kg averaged over 10 g in U.S. and Europe, respectively.

The local SAR is determined experimentally by measuring either the local electric field or temperature rise caused in the biological tissue

$$SAR = c\frac{\Delta T}{\Delta t} = \frac{\sigma|E|^2}{\rho}[W/kg]$$

where c is the specific heat of the tissue in J/g/℃, $|E|$ is the electric field strength (RMS value) in V/m, σ is the conductivity in S/m, ρ is the mass density in g/cm^3, and $\Delta T/\Delta t$ is the time derivative of the temperature.

■ Measurements And Result

In this paper we investigate SAR dependence for cellular phones with EMI paint and without EMI paint inside the phone case. To measure the SAR, we use the flat phantom and the simulated liquid with human head electric parameters at 835 MHz. For the analysis of SAR dependence, the radiated electric and magnetic field from the phones are measured in free space. The effect of removed EMI paint in the phone decrease 17 % and 16 % in $|E|^2$ inside the phantom and $|H|^2$ in free space, respectively (see Table 1).

Table. 1. The normalized square of the induced E-field strength and incident H-field strength (*w_max*: maximum value for the phone with EMI paint)

EMI condition for front case of phone	$\frac{\|E\|^2_{\max}}{\|E\|^2_{w\_\max}}$ in flat phantom	$\frac{\|H\|^2_{\max}}{\|H\|^2_{w\_\max}}$ in free space
With EMI paint	**1**	**1**
Without EMI paint	**0.83**	**0.84**

As it is known well, SAR is proportional in square of a magnetic field more preferably than electric field that is radiated in antenna.

$$SAR = \frac{\sigma}{\rho}\frac{\mu\omega}{\sqrt{\sigma^2+\varepsilon^2\omega^2}}(1+c_{corr}\gamma_{pw})^2 H^2$$

where SAR is induced value at the surface of a flat phantom, H is the incident magnetic field, γ_{pw} is the plane-wave reflection coefficient for the H-field and c_{corr} is the correction coefficient[2]. And the surface current is increased by EMI paint inside the phone case($\mathbf{J}s=\mathbf{n}\times\mathbf{H}$).

Consequently, the EMI paint of the inside phone case result in increase SAR.

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Universal Rules of Synergistic Interaction and Their Significance in EMF Application

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■ Introduction

The widespread and increasing use of electromagnetic fields and radiation (EMF) has greatly increased the possibility of exposure of both occupational and general population to RFR combined with various environmental factors including a higher ambient temperature. This study was designed to implement the following purposes: (a) to reveal the basic features of the synergistic effects observed after combined actions; (b) to suggest a mathematical model to explain the basic features; (c) to estimate synergistic effects of microwave (7 GHz) power combined with a higher environmental temperature or a physical work; (d) to discuss possible significance of these results in microwave standard setting.

■ Basic features of synergy

Using our own results and a number of papers published by others the following general rules have been established for synergistic interactions of the simultaneous action of hyperthermia with ionizing radiation, ultraviolet light, ultrasound, and with some chemicals for various cellular systems. (1) For any constant rate of exposure, synergy can be observed only within a certain temperature range. (2) Inside this range there is a specific temperature that maximizes the synergistic effect. (3) An increase in exposure rate resulted in an increase of this specific temperature and *vice versa* (4) For a constant temperature at which the irradiation occurs, synergy can be observed within a certain dose rate range inside which an optimal dose rate may be indicated that maximizes the synergy. (5) As the exposure temperature is reduced, the optimal dose rate decreases and *vice versa*.

■ Mathematical model of synergy

To explain and describe the basic features revealed, a simple mathematical model was employed. The model suggests that synergism is related to additional effective damage arising from the interaction of sublesions induced by each agent. These sublesions are considered to be ineffective when each agent is taken alone. The nature of effective damage and sublesion remains to be elucidated. It was shown that the model describes experimental data for a number of biological objects, end points, and agents combined. Moreover, the model predicts the greatest value of the synergistic effect, the condition under which it can be achieved as well as the dependence of synergy the intensity of agents applied. It would be of interest to clear up whether the general rules of synergistic interaction and the model suggested could be applied to EMF combined with a higher ambient temperature or a physical work.

■ The effects of EMF combined with ambient temperature or physical work

The effects of EMF (7 GHz) combined with ambient temperatures or physical work was obtained using rabbit or rat heating. The effect of microwave energy absorption is expressed in the animal in the form of heat. The exposed animals which are not able to compensate for this heat input showed an uncontrolled rise in body temperature.

Using experimental data observed, the synergistic effects between EMF and either an ambient temperature (rabbits) or physical work (rats) have been established. In both cases synergistic interaction was observed only inside a certain range of specific absorption rate (SAR). Within this range an optimal value of SAR can exist at which the synergy is maximal. Both increase and decrease in the EMF intensity from this optimal value resulted in a decrease of the synergy. In accordance with the model considered the bell-shaped relationship between the synergy and the power flux density should be shifted to lower intensities with an decrease in ambient temperature and *vice versa*. This prediction was tested for rabbit heating only at one experimental condition. The results obtained are in qualitative agreement with the model prognosis.

■ Conclusions

A. Synergistic interaction was observed between microwave energy (7 GHz) and additional thermal load produced by physical work or high ambient temperature.

B. An optimal SAR both for a constant physical work and ambient temperature can be indicated, which resulted in the greatest synergistic interaction.

C. The mathematical model of synergistic interaction was valid to describe and predict the results observed.

D. The decrease in ambient temperature resulted in a decrease in microwave intensity to provide the highest synergy. It means that the synergy can be observed, in principle, for low EMF intensity.

E. The results obtained would be useful for further developing and harmonisation of EMF safety standards.

PROBE DESIGN AND FABRICATION FOR MEASURING NEAR FIELD

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■ Introduction

There has been an increase in the public concern about possible health risks through electromagnetic exposure from mobile phones. A specific absorption rate (SAR) measurement has been required to demonstrates the compliance of mobile phone with safety limits. For the purpose of estimating SAR, a miniature electric probe has been studied from 1970's[1],[2].

In this paper, a three-axis electric probe which is capable of measuring the three vector components of an unknown radiating field has been developed. The probe is designed to detect frequencies from 300 MHz to 3000 MHz covering current mobile communication frequencies. The probe consists of a dipole antenna, a zero bias Schottky diode and a highly resistive transmission line(T/L).

■ Design and Fabrication

Design parameters were extracted by an equivalent circuit of the electric field probe[1],[2]. The performance of the probe could be predicted by a simulation.

Table 1. Design parameters of probe

Parameter	Design value
Frequency range	300 ~ 3000 MHz
Diode	HSCH-5331
Antenna length	3.25 mm
Antenna width	1.0 mm
T/L length	300 mm
T/L width and spacing	Each 0.25 mm
T/L equivalent resistance	1.0 MΩ
T/L equivalent capacitance	60 pF

The shape of the probe was shown in Fig. 1. A diode was placed at the center of the dipole antenna. The thick-film technique was employed for the construction of the dipole antenna and T/L on the substrates (alumina) and then the substrates were adhered on a triangular type guide for the orthogonal characterictics.

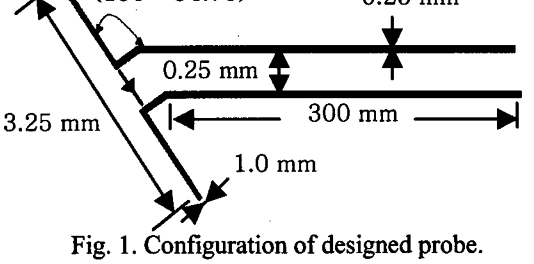

Fig. 1. Configuration of designed probe.

■ Results and Conclusions

The three-axis probe had been tested in TEM cell[3]. Due to the limitation of setups, the test was carried out below 1000 MHz. Fig. 2 shows the result of linearity evaluation at 1000 MHz. The probe response increases linearly as the incident power strength increases from 10 to 40 dBm. In Fig. 3, it is showed that the probe response varies very slightly from approximately 100 MHz to 1000 MHz with the given power strength of 15 dBm.

In conclusion, the probe can be used to detect the power strengths of 10 ~ 40 dBm at the frequency range between 100 MHz and 1000 MHz.

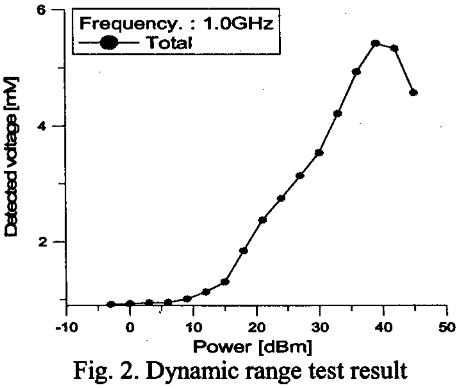

Fig. 2. Dynamic range test result

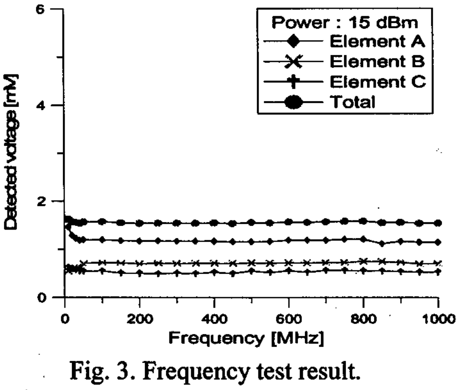

Fig. 3. Frequency test result.

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THE EFFECT OF MAGNETIZED PHYSIOLOGICAL SOLUTION ON THE PERFUSED SNAIL HEART CONTRACTILITY

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■ Introduction

Previously it was shown that SMF with 27mT intensity has depressing effect on the specific electrical conductivity (SEC) of distilled water (DW) and water solutions[1], as well as on the growth and division of E.Coli K-12 Lon mutant[2]. The present work was aimed at checking the effect of 27mT SMF treated physiological solution on the contractile activity of intracardially perfused isolated *Helix pomatia* snail heart.

■ Observations

Helix pomatia snail heart was chosen as an experimental model. After the heart had been isolated, a cannula was inserted therein, through which solutions with various compositions were perfused intracardially. To monitor the heart contraction a special setup was designed transducing the isotonic heart contractions into the electrical signals for the subsequent recording with a potentiometer. The perfusing solution was treated by 27mT SMF for 120 min.

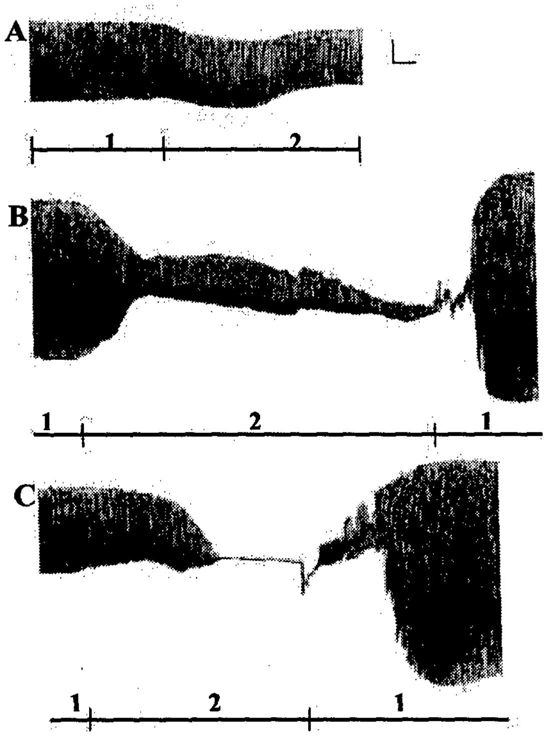

Fig. 1. The effect of magnetized physiological solution (MPS) on snail heart contractility and time dependency of heart sensitivity threshold on it. A-10, B-30 and C-60 min after applying. 1-physiological solution, 2-physiological solution previously exposed to magnetic field.

The myograms in Fig. 1 show that SMF treated physiological solution causes negative chronotrop and inotrop effects up to stopping the heart contractility in the phase of diastole.

■ Conclusion

As the heart contractility depends on the intracellular content of Ca ions which is regulated by the cyclic nucleotide dependent Na:Ca exchanger. The more detailed investigation of MPS induced effect on heart contractility in activated and inactivated states of cAMP and cGMP pathways has demonstrated that MPS induced inhibition of heart contractility is due to the activation of cGMP dependent Na:Ca exchange in reversal mode, i. e. Na influx accompanied by Ca efflux.

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2. Ayrapetyan S. N. *et al.*, Microbiology. 70(2), 248-252, 2001.

DIFFERENCES OF SAR'S BETWEEN VARIOUS HEAD MODELS FOR HANDSET EXPOSURE

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■ INTRODUCTION

In this paper, in order to find the effects of head size or shape on electromagnetic absorption characteristics, the auricle-removed anatomical model (Model A) and a simple head model (Model B) are scaled and then SAR distributions for these models exposed to each mobile phone operating at 835 MHz and 1765 MHz have been investigated using the FDTD method.

■ NUMERICAL MODELS

We have implemented a new head model based on MR and CT images of a volunteer whose head shape is very close to the domestic (Korean) standard for the age group of 18~24. The brief physiques of the models are given in Table 1. The auricles of the original model were removed carefully. This model (Model A) was scaled by five factors of 90, 95, 100, 105 and 110 %. The FCC (Federal Communications Commission) data were used for electrical properties such as dielectric constant and conductivity of each tissue type. In order to investigate the tendency in SAR distributions more accurately, a simple head model (Model B) with the domestic standard sizes of head width, head breadth, and chin-vertex length was implemented. It was scaled by 5 % step from 80 % to 120 % for each head parameter and for all head parameters, respectively. These simple models were simulated with the homogeneous tissue properties of ε_r(dielectric constant) = 55.192 and σ(conductivity) = 0.921(S/m) at 835 MHz, ε_r = 55.386 and σ = 1.417 at 1765 MHz, and ρ(mass density) = 1040 (kg/m^3).
The outer size and the antenna length of the numerical phone model are 108×46×22 mm and 64 mm at 835 MHz, and 100×44×24 mm and 44 mm at 1765 MHz, respectively. These sizes followed approximately those of typical mobile phones. The antenna position on the top surface of the body at 1765 MHz is farther by 2 mm than at 835 MHz from the phone surface facing the cheek. The plastic casing was modeled as a dielectric insulator with ε_r=4.0 and thickness of 2 mm. The test positions for both of the head models are shown in Fig. 1.

■ RESULTS

From the calculated results for Model A, in a larger head, a higher local SAR is appeared at 835 MHz. At 1765 MHz, the differences of the local SAR's among the head models are insignificant since the superficial absorption is dominant compared with the effect of head size. Especially, from the SAR distributions at 835 MHz, it is found that for a larger head, the SAR values are higher near the phone, but the area with the lower SAR level grows larger at the opposite side.
The SAR results for Model B show this trend more clearly and in detail. The results for all cases except head breadth variation at 835 MHz supports the fact that a larger head produces a higher local SAR and a lower whole head-averaged SAR. However, at 1765 MHz, the local SAR differences between the scaled models are very slight. It suggests that the frequency is higher, the effect of the head shape on the local SAR grows weaker and superficial absorption is primary factor for SAR result.

■ CONCLUSIONS

The major findings are summarized as follows: 1) The deeper EM energy penetration into a head occurs at 835 MHz than at 1765 MHz, 2) At the both frequencies, a larger head produces a lower whole-head averaged SAR, 3) The head geometry strongly influences on localized SAR evaluation at 835 MHz and the trend of increasing localized SAR for a larger model have been observed. However, The head geometry is no longer a factor influencing on the localized SAR at 1765 MHz and the maximum local SAR results are constant.
At present, SAR evaluations by the FCC and CENELEC are only performed with large adult phantom. Our results support that they consider the worst case of the phantom because only localized SAR values are used for evaluating mobile phones. However, the safety guidelines themselves are based on the whole-body averaged SAR that brings about the biological hazard due to temperature rise. Therefore, the greater whole-head averaged SAR in a smaller head model should be considered. Also, the above results can be used to investigate differences of biological effects according to human species and ages.

TABLE 1. Comparison of physiques of the simulated models [unit: mm].

	Model A (Volunteer)	Model B (Domestic standard)
ⓐ Head breadth	160	158
ⓑ Head length	187	181
ⓒ Chin-vertex length	229	232

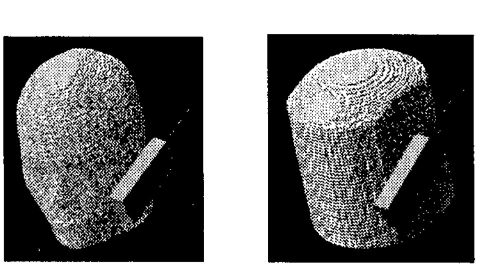

Fig. 1. Test positions.

ONE POSSIBILITY TO SETTLE THE DIFFERENCES BETWEEN THE "DOSE APPROACH" AND SAR VALUES

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Radiofrequency (RF) electromagnetic (EM) human exposure is in the centre of the main research studies in the world. It is connected with the question whether RF radiation is dealing with the increase of cardiovascular, CNS, autonomic nervous system diseases, with cancer, mental and sleep disturbances, etc. Most of the new technologies are connected with developing new sources of EM radiation. This is one of the reasons most of the people to be afraid of the RF exposures.

Most of the new standards for RF radiation use the SAR values as criteria for developing limits. The other school, the Eastern European one uses a parameter called "energetic loading of the human body" which is different energetic value characterized the RF radiation exposure. The latter value is a part of the "dose approach" used in the sited standards.

The both parameters – SAR and energetic loading are very similar, and they both are dosimetric values. Calculations from one to the other parameter could be made on the basis of the existing information from the design of the study in most cases. As an example, the way of this how from the Bulgarian limits (the energetic loading parameters) were calculated SAR values it was shown in Varna on the Regional East European Standards Harmonization Meeting. There it was clear that the opinion about "the very strict limits" used in East Europe became only a myth.
Here, we try to make calculations shown the possibility to use the "dose approach" and SAR criteria, both for RF human exposure studies. As an example, a calculation of SAR is made on the basis of the energetic loading of the organism for broadcasting occupations.

This approach could be one possibility to find tangents between different schools for developing standards.

Update on Mobile Telephony Related Research World Wide: Using the WHO Database

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■ Introduction

About 300 studies have been initiated using cell culture, animal, and human models to investigate whether exposure to analog, CDMA, or TDMA-modulated communication signals can cause adverse health effects. Almost 200 of these studies have been reported, with the vast majority reporting no observed effects. Tables of these studies will be provided derived from the WHO-EMF database (http://www-nt.who.int/peh-emf/Database.htm). The results of studies describing cancer related endpoints (161 total with 97 completed) as well as other relevant studies addressing cancer from the larger RF bioeffects database (see IEEE database on the WHO website) will be used by the International Agency for Research on Cancer (IARC) in 2004 or 2005 to evaluate radiofrequency (RF) emissions as a potential human carcinogen. In such evaluations, epidemiological studies will carry the most weight. Animal studies will play an important role when epidemiological studies are weak or not definitive. In vitro studies generally have only a supporting or clarifying role in these evaluations. A similar evaluation of non-cancer studies is planned by WHO shortly after IRAC completes its evaluation. Currently there are a total of 137 mobile telephony related non-cancer studies with 96 completed.

■ Observations

Thirty epidemiological studies have been initiated to examine the potential for mobile telephony RF exposure to cause adverse health conditions. The majority of these address cancer and sixteen are part of a large study coordinated by IARC. Twelve studies have been completed, seven addressing cancer. Four large recent studies report no observed effects. Of the thirty-two long-term animal studies that have been initiated to investigate cancer endpoints following RF exposure seventeen have been completed. One study has reported effects on transgenic mice and a second reported equivocal results. Two replications of each of these studies are underway. There are a total of 101 in vivo studies addressing various health conditions with the majority showing no effects of non-thermal RF exposure, although a few have reported positive findings requiring further study. There are also 101 in vitro studies addressing numerous endpoints that have been initiated. Sixty-five of these are now complete with the majority reporting no observed effects. Finally, a large number of human studies addressing subjective disorders such as sleep disturbance, headaches, cognitive function and memory have been performed, with some effects being reported.

■ Conclusions

The weight of evidence on whether exposure to mobile telephony emissions is carcinogenic has led expert panels around the world to conclude that RF emissions do not initiate cancer and that the available evidence suggesting that RF emissions promote cancer is not sufficiently persuasive. In regards to non-cancer studies reporting positive effects, there is no consistent pattern of results that would identify an obvious mechanism other than heat. Those studies reporting effects at non-thermal RF exposure levels, in general, have either failed to be replicated in independent laboratories or remain unconfirmed because replication attempts have not been completed to date. In addition, no plausible mechanism is evident to explain these "positive" findings. All reported positive studies which appear to have adequate experimental design, including appropriate dosimetry, are in fact being replicated through further research. Completed, published replication studies are important to the proposed IARC evaluation of cancer and the WHO evaluation of non-cancer endpoints.

Developmental Toxicology Evaluation of ELF Magnetic Fields in SD Rats

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■ Objective

Recently, there is an increasing nationwide concern in Korea that exposure to electric and magnetic fields in the home environment may not be safe in humans. To identify possible effects of horizontally polarized magnetic fields (MF) exposure on fetal development, timed-pregnant female Sprague-Dawley rats (24/group) received continuous exposure to 60 Hz MF at field strengths of 0 Gauss (sham control), 50 mG, 833 mG, or 5 G. Dams received MF or sham exposures for 22 hr/day on gestation day 6 through 20. Experimentally generated MF were monitored continuously throughout the study.

■ Materials and Methods

MF exposure and monitoring instrumentation were constructed by Korea Electrotechnology Research Institute. And MF monitored continuously throughout the study. Sham exposure or exposure to 60 Hz MF for 21 hr/day from days 6~20 of gestation. Target MF strengh are as folllows.

- 0 mGauss(G, sham control)
- 50 mG: average MF strength under the domestic 765 kV power cable
- 833 mG: exposure level recommended by WHO/ICNIRP
- 5 G: maximally attainable MF strength within this exposure system

Animals for experiment are as follows.

- Sprague-Dawley Crj:CD rats (Breeding Facility TRC, KRICT)
- No. of mated females : 22/group
- Age on supply : 12 weeks old
- Housing : polycarbonate cage (cages rotated within the racks on a 5-day basis)

■ Environmental conditions

Animal rooms specifically designed and constructed for studies of biological effects of MF (Samkwang Lab. Co.) Animals kept under standardized environmental conditions. (23±3℃, 50±10%, 10~20 fresh air changes/ hr.) All of the studies were undertaken "blind".

■ Observation of dams

- Clinical signs : Once a day
- Body weight: On days 0, 6, 9, 12, 15 and 20 of gestation
- Food consumption: On days 1, 7, 10, 13, 16 and 20 of gestation
- Necropsy findings: On day 20 of gestation
- Measurement of organ weights : brain, adrenal gland, liver, spleen, kidney, heart, ovary
- Hematology : WBC, RBC, HGB, HCT, Platelet, Differential leucocyte count, Prothrombin time
- Clinical chemistry : ALT, AST, ALP, GLU, TP, ALB, A/G, BUN, CRE, TCHO, TBIL, TG, PL-E, Ca, IP, Na, K, Cl
- Caesarian section : Implantation sites, corpora lutea, living fetuses, dead fetuses, resorptions, sexing,

■ Statistical analysis

Variables such as body weight of dams, hematological values, serum biochemical values, implantation rate, litter size, and number of live fetuses, fetal weight were used by One-way ANOVA and Scheffe's test. And Fetal deaths was used by Kruskal-Wallis test and Fischer exact test. Incidence of external, visceral and external malformations in fetuses were used by $x2$ test and Fischer exact test. A difference was considered statistically significant at $p \leq 0.05$.

■ Results

There were no evidence of maternal toxicity or developmental toxicity in any MF-exposed groups. Mean maternal body weight, organ weights, and hematological and serum biochemical parameters in groups exposed to MF did not differ from those in sham control. No significant differences in fetal deaths, fetal body weight, and placental weight were observed between MF-exposed groups and sham control. External, visceral, and skeletal examination of fetuses demonstrated no significant differences in the incidence of fetal malformations between MF-exposed and sham control groups. In conclusion, exposure of pregnant Sprague-Dawley rats to 60 Hz at MF strengths up to 5 G during gestation day 6-20 did not produce any biologically significant effect in either dams or fetuses.

THE EFFECT OF EMF ON WATER SPECIFIC ELECTRICAL CONDUCTIVITY AND WHEAT SPROUTING

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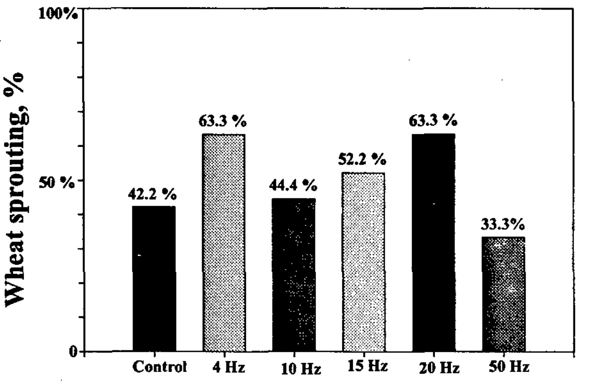
Introduction

There are abundant published data on the effect of weak physical signals on cell functional activity. However cell targets for these signals are not established yet. Since water is the main component of biological systems and all the metabolic processes take place in aqueous medium it was supposed that the minor changes in the physico-chemical properties of water can significantly modify cell functional activity. Previously it was shown that low frequency (LF) EMF with 12mT intensity has frequency dependent effect on the specific electrical conductivity (SEC) of distilled water (DW) and water solutions[1], as well as on the growth and division of E.Coli K-12 Lon mutant[2]. The most pronounced depressing effects of LF EMF on SEC of water and on the functional activity of microbes were observed at the frequencies of 4-10Hz at 12mT intensity. The existence of this frequency "window" at lower intensity EMF (less than 5mT) is not studied yet. Therefore the purpose of the present work was to check the frequency-dependent effect of LF EMF on SEC, pH of fresh DW and the latter effect on the process of wheat sprouting at the 2,5mT EMF.

Observations

Previously it was shown that SEC of DW depends on its age[3]. In present experiments the fresh (less than an hour age) DW was used. The SEC of DW was measured using special glass test chamber (1cm in diameter; with 5ml volume) with two electrodes inside. The 1cm^2 platinum electrodes, spaced by 0,5cm to each other were connected with the conductivity gauge which was allowing to measure SEC at less than 10^{-9}A, 70Hz currents. To expose the DW to EMF a generator of sine-wave with special coil generating 2,5mT EMF was used. SEC of DW treated by 4, 10, 15, 20, 50 Hz frequencies and 2,5mT intensity EMF was measured. Then the biological effect of magnetized DW samples on the process of wheat sprouting was checked in Petrie's dishes. During 30 min the SEC of untreated DW increased by 8%, while in same period the SEC of DW treated by 4 and 10Hz EMF decreased by 7,3% and 3%, by 15 and 50Hz increased by 9% and 4,6% accordingly. The study of pH of the same samples of DW showed that during 30 min pH of untreated DW increased by 2,5%, while in EMF treated samples by 4, 20 and 50Hz it decreased by 2.3, 4.5 and 4.5% accordingly. In the cases of DW treated by 10 and 15Hz EMF insignificant changing (by 0.18%) in pH were recorded. The non-adequate dependence of DW SEC and pH on EMF frequency allows us to suppose that EMF–induced changes of DW SEC cannot be explained by changing the only proton concentration in DW. The most pronounced changes in SEC and pH of magnetized DW were observed at 4 and 20Hz frequencies. It is interesting to note that the same frequency dependent effect was observed when studying the effect of these samples of DW on wheat sprouting (Fig. 1). 50Hz-treated DW had inhibiting effect on it.

Fig. 1. Frequency dependent effect of EMF treated distillated water on wheat sprouting after two-day latent period.



Conclusions

LF EMF has frequency-dependent effect on SEC and pH of DW, and the latter has adequate biological effect on wheat sprouting. However, the EMF frequency dependence of SEC and the biological effect at 2,5mT intensity is less pronounced than it was demonstrated earlier at 12mT[2]. All the presented data serve as an additional evidence for the hypothesis according to which the EMF-induced water structure changing is an important pathway through which the biological effect of EMF is realized.

1. Ayrapetyan S. N. *et al.*, Bioelectromagnetics, 15, 133-142, 1994.
2. Ayrapetyan S. N. *et al.*, Microbiology. 70(2), 248-252, 2001.
3. Stepanian R. S. *et al.*, Biophysics 44(2), 197-202, 1999.

Long-Term Effects of 60-Hz Electric vs. Magnetic Fields On IL-1 and Other Immune Parameters in Sheep

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■ Introduction and Objective

There has been a considerable concern and controversy about the potential health effects of exposure to extremely low frequency electric and magnetic fields that produced 50-60Hz distribution and transmission lines or electrical appliances. The purpose of this study is to provide a brief overview of the immune system and review some of the research studies that have examined whether EMF(Electric and Magnetic Fields) exposure may affect immune responses or not.

■ Method

This study was designed to assess the effect of exposure to long-term low-frequency EMF from a 500-kV transmission line on immune function in sheep. The studies were conducted near the Bonneville Power Administration Ostrander Substation, 40-km southeast of Portland, Oregon (45° 24′ north latitude). Figure 1 and Figure 2 show that the test site configuration and the overview of test site respectively.

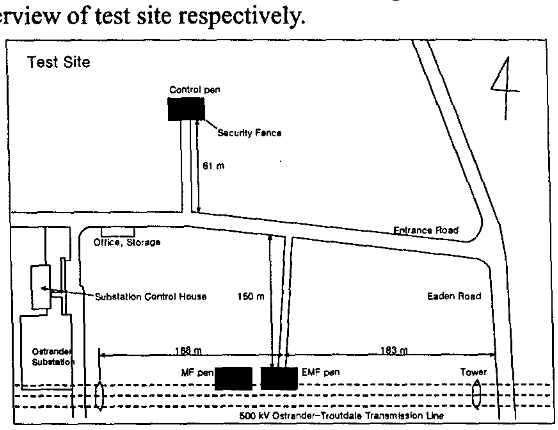

Fig. 1 Test site configuration

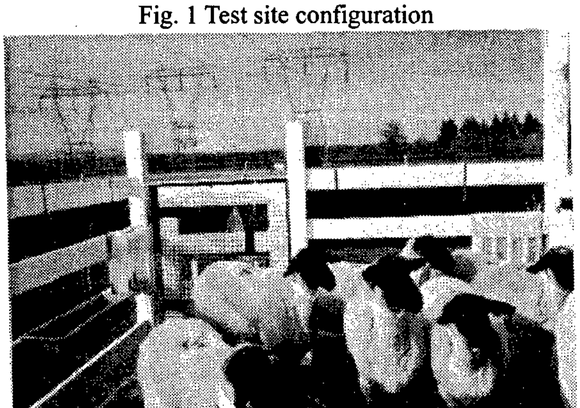

Fig. 2 The overview of test site

The sheep were randomized into 3 groups of 15 sheep each. One group of sheep was placed in the EMF pen and a second group was placed in the shielded MF pen located next to the EMF pen. The MF pen was constructed and shielded with wire to effectively eliminate the electric field while not significantly affecting the magnitude of the magnetic field. And the third group of sheep was placed in the control pen located several hundred meters away from the transmission line. In this study, the control group was exposed to a mean electric field of <0.005 kV/m and a mean magnetic field of 0.3 mG. The EMF group was exposed to a mean electric field of 3.8 kV/m and a mean magnetic field of 35 mG. The MF group was exposed to a mean electric field of <0.01 kV/m and a mean magnetic field of 35 mG.

During the exposure periods, blood samples were taken from all sheep monthly. Interleukin-1 activity, Leukocyte Proliferation, Leukocyte counts, and Interleukin-2 activity were examined from each monthly bleed. The weight and the health also were noted. An antibody production was assessed and a complete blood chemistry analysis was done towards the end of the exposure periods. Leukocyte proliferation stimulated by lipopolysaccharide(LPS) was examined at the conclusion of the study with all sheep removed from the pens and exposed to background EMF.

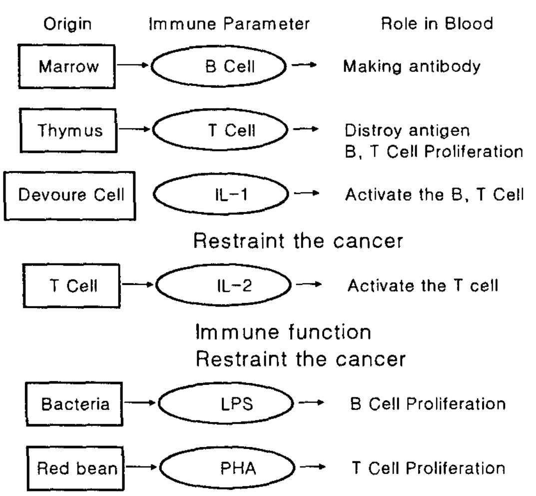

Fig. 3. Concept of Immune Parameter

■ Results and Discussion

This study represents the second portion (14 months) of a long-term (27 months) study to evaluate the effect of EMF exposure on immune function in sheep. The main finding of this study was that an exposure to EMF or MF did not have a significant impact on the number of immune parameters, including IL-1, IL-2, LPS, PHA, and the number of white cell during total periods of 14 months.

The results show that the electric and magnetic fields from the 500-kV transmission line have no effects on the immune system in sheep. Furthermore, the sheep were very healthy during exposure tests. The detailed results will be discussed at the meeting.

THE NOVEL MODEL OF MOBILE PHONE ANTENNA FOR LOW SAR

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■ INTRODUCTION

The conventional mobile phone has external antenna (ex. monopole and retractable) at the outside of the mobile phone, which has omni-directional radiation patterns to sense the electromagnetic waves in the all directions. Because lots of the electromagnetic waves radiated from mobile phone are absorbed into the body, particularly in the head of body which is close to the mobile phone, the effect to the body by the electromagnetic waves resulted from the mobile phone have been studied in various ways. Until now, it has been reported that electromagnetic energy radiated from mobile phone would cause adverse effects on human body, especially, human head.

Thus, it is necessary to develop mobile phone antennas to reduce radiation toward user's head. In this paper, a novel antenna is proposed and its characteristics are presented.

■ ANTENNA CONFIGURATION

The SAR is defined as following equation using a theory of poynting vector for electric field which is changing into sine waves, and it is known to the superior variable for specifying an interaction between the electromagnetic waves and the human body;

$$SAR = \frac{\sigma}{2\rho}|E_i|^2 \quad \text{..........................(1)}$$

where σ is conductive rate of element in radiated frequency (S/m), ρ is a density of elements [kg/m^3], and E_i is an intensity of electric field in the interior element [V/m]. Because the SAR is proportional to the square of the intensity of electric field, the conductive rate and the density are constant, and are inversely proportional to the square of distant from a source to the element, as shown in the equation (1). Federal Communications Commission (FCC) has been specified tightly a base amount for the SAR of the head (1.6 mW/g at 1g averaged) regarding the mobile phones.

For low SAR, the novel model of mobile phone antenna is proposed. In order to reduce the exposure to human head, monopole antenna would be mounted on internal printed circuit board in the opposite side of ear piece for mobile phone. Because internal printed circuit board plays a role on reflection plate, the resonance of antenna would be disappeared. This is the reason that monopole antenna could not be mounted in the inside of mobile phone. Thus, electromagnetic absorber is inserted between printed circuit board and internal monopole antenna for SAR reduction and antenna resonance, which absorbs electromagnetic waves toward human body generated from mobile phone and prevents distortion for the resonance of proposed antenna.

■ RESULTS

The conventional mobile phone monopole antenna has omni - directional radiation pattern for receiving signal from the all directions. When human head is located in head direction, lots of emitted power is absorbed in human head and antenna efficiency decrease considerably as a result of distorted radiation pattern by human body.
But proposed antenna has the reduced radiation pattern toward human head direction. So, it can be have lower SAR value than external mobile phone antenna. Because electromagnetic waves are absorbed into absorber in the proposed antenna set, the difference of efficiency with or without user is less than external mobile phone antenna, and the efficiency in use is similar with that. Thus, the proposed antenna has similar efficiency with general monopole mobile phone antenna and lower peak SAR value than that.

■ CONCLUSIONS

In this paper, a novel mobile phone antenna, corner-mounted antenna set, is designed to reduce SAR (Specific Absorption Rate) on the human head, and the results are compared with conventional mobile phone antenna. The antenna element is mounted on the corner of internal mobile phone case, and electromagnetic absorber is located between antenna element and printed circuit board (PCB). The characteristics of proposed antenna are shown and radiation pattern of it is compared with that of conventional mobile phone antenna. It is an internal antenna for compact mobile design with small size and low profile, and it has radiation pattern for safe of mobile phone user.

Effect of 1.765GHz radiofrequency radiation on proliferation, stress and gene expression *in vitro*

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■ ABSTRACT

To investigate the acute effects of 1.765GHz RF, we exposed four types of human and mouse cells at 1.5W/Kg or 75W/Kg SAR for 30min to 12 hr. Upon 1.7GHz radiation, we could not find any alteration in proliferation or apoptosis within 72 hours. Instead we just detected increased actin polymerization in mouse fibroblast. Using cDNA microarray containing 4608 human cDNAs, we describe the effect of radiofrequency radiation in gene expression profile in detail. Jurkat T cells were subject to 1.7GHz (CDMA) radiofrequency at 75W/Kg for 1 hour. Each sample was examined in duplicate and all datasets were normalized by rank invariant method. The pattern of gene expression was generally similar to other stress responses, but we could identify unique pattern of gene expression upon radiofrequency radiation. We suggest that 1.765GHz RF did not induce the cell growth or death acutely and induce unique responses against gamma-radiation.

■ INTRODUCTION

Although hazards from exposure to high-level EMF fields were relatively well established, no known health hazards were associated with exposure to low-level EMF sources emitting fields too low to cause a significant temperature rise in tissues. These might include *in vitro* studies of cell proliferation, gene expressions, immunological alterations for EMF field effects. *In vivo* studies should focus on the potential for cancer initiation, promotion, co-promotion and progression, as well as possible synergistic effects associated with chronic radiofrequency exposure. Research is needed to determine whether low-level EMF exposure can cause DNA damage or influence the function of immune system. One mechanism through which radiofrequency radiation could stimulate cancer induction is via altered expression of oncogenes and/or tumor suppressor genes that regulate normal and neoplastic growth.

In this study, we will examine i) whether radiofrequency can modulate the alterations of gene expression using DNA chip, ii) whether human fibroblast show any change in proliferating potential after chronic exposure to radiofrequency. Next we will expand our findings to iii) *in vivo* experiment using various types of mice including tumor-prone models.

■ RESULTS AND DISCUSSION

We established 1.765GHz *in vitro* exposure system. Using this system. Various types of cells from human and mouse were tested for their proliferative potentials, but RF did not affect them even at 75W/Kg SAR for 12 hrs. We also found no gross abnormalities in chromosomes of Jurkat T cells in karyotyping experiments. However, C3H10T1/2 cells showed increased polymerization by 1.7GHz RF exposure for 12 hours. Using cDNA microarray, we screened the 4608 human genes for their expression in radiofrequency radiation. Stimulation by 1.765GHz radiation at 75W/Kg for 12 hours induced sets of genes related to signal transduction and transcription factors, and suppressed cytokine and metabolism. From these results, 1.765GHz radiation did not induce any gross cellular changes and cell proliferation, but the expression of genes were changed upon stimulation.

Design of PIFA on IMT-2000 Handset for SAR Reduction

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■ Introduction

In this paper, planar inverted F antenna (PIFA) on IMT-2000 handset for specific absorption rate (SAR) reduction is designed. Type of PIFA with sorting pin is investigated and studied for IMT-2000 handset.

The gain and radiation pattern of a PIFA is similar to those of monopole and helical antennas. But bandwidth of PIFA is narrow bandwidth. However, the reduction of radiated field toward the direction of human head is very attractive merit of PIFA. Also, the low-profile characteristic of a PIFA makes it suitable for using as an internal antenna for a handset.

■ Simulation

The PIFA consists of a ground plane, a top plate element, a feed wire attached between the ground plane and the top plate, and a shorting pin that is connected between the ground plane and top plate. The antenna is fed at the base of the feed wire where the wire connects to the ground plane. The effects of the ground plane and the different parts of the antenna must be considered in the overall design. The design variables for this antenna are the height, width, and length of the top plate, the width and location of the shorting plate, and the location of the feed wire. Resonance characteristics with variety of design parameters are analyzed. The bandwidth of a PIFA using a shorting pin is largely dependent upon shorting pin location. The position of handset mounting PIFA is suggested that is tilted by 60°. Face of antenna is in the opposite direction from the human head. Length of monopole antenna, $\lambda/4$, is designed and compared with PIFA in bandwidth and SAR.

The finite-difference time domain (FDTD) method is based upon the explicit solution of Maxell's equations in differential form in the time domain. The radiation pattern for an antenna is obtained by computing and storing the tangential time-domain fields over a surface which completely encloses the antenna using FDTD, and subsequently using the equivalence principle to determine the field values in the far-zone. Using FDTD method, the SAR from an IMT-2000 handset is computed

■ Results

At center frequency of 2.04 GHz, the calculation result that the bandwidth of designed PIFA is 216MHz and radiation pattern is similar to that of a $\lambda/4$ monopole antenna except that the directivity of a designed PIFA in the direction behind the ground plane is approximately lower than that of forward direction. 1g and 10g peak averaged SAR of PIFA are 0.9869 W/kg and 0.453 W/kg. The SARs caused by monopole antenna are 1.5785 W/kg and 0.8446 W/kg. The SARs caused by PIFA are about 50% lower than those of monopole.

■ Conclusions

In this paper, the detections of 1g and 10g averaged SAR on human head caused by IMT-2000 handset are analyzed and discussed using FDTD method. The conventional monopole antenna and PIFA are used in the computational model to apply to the antennas mounted on handset.

While the radiation pattern of monopole antenna is omnidirectional, that of PIFA is directional and SAR caused by the PIFA is less than that by the monopole antenna.

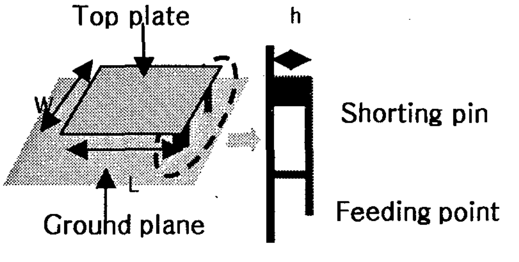

Figure 1. Geometry configuration of PIFA

■ References

[1] M. A. Jensen and Y. Rahmat-Samii, "Performance analysis of antennas for hand-held transceiver using FDTD," IEEE Trans. on Ant. and Propa. vol. 42, no. 8, Aug. 1994.

[2] K. S. Yee, "Numerical solution of initial boundary value problems involving Maxwell's equation on isotropic media,' IEEE Trans. on Antennas and Propagation, vol.14, pp.302-307, May 1966

[3] K. S. Kunz and R. J. Ruebbers, "The finite difference time domain method for electromagnetics", CRC Press, 1993.

[4] J.D. Park and N. Kim, "SAR analysis on human head caused by PCS handheld telephone", BEMS Annual Meeting, 1997.

Relationship Between Function of Human Brain and Handheld Cellular Telephone Use in Korean Using EEG Test

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Institute of Environmental & Industrial Medicine, Hanyang University, Seoul, Korea [1]
Department of Neurology, Hanyang University Hospital, Seoul, Korea [2]

■ Introduction and Objective

Arguments of relationship between human health effects and handheld cellular telephones become increasingly of considerable interesting in Korea in recent years and lead to necessity of Korean population. The purpose of this study is to evaluate radiofrequency exposure from handheld cellular telephones which may have the potential to influence on the electric functions of the human brain in occupational Korean population.

■ Method

Subjects were 16 physically and mentally healthy male volunteers who were 24-34 years of age, 174.2 ± 2.6 ㎝ in height and 68.1 ± 9.5 ㎏ in weight, and 22.34 ± 4.2 ㎏/㎡ in body mass index(BMI). All volunteers provided written informed consent. Subjects were assigned to three group ; 4 subjects in non-using, 6 subjects in long-term(more than 5 years) using, and 6 subjects in short-term(less than 2 years) using handheld cellular telephones group. An experimental study was performed for August 2001. Each EEG-recording 40min consisting of 30min field exposure and 10min measurement. With the use of EEG recording data collected with NEVROFAX instruments(Nihon Kohden Inc.) EEG activity was recorded simultaneously from both symmetrical cortices using a 16-channel polygraph with the bandwidth set at 1 to 70Hz. The frequency spectra of 10-sec successive EEG epochs in the range of 1-70Hz were analyzed "on-line" on an IBM-compatible PC/386 personal computer. Each epoch was digitized with a multichannel A/D DT 2821 converter suing a sampling rate of 20 and therefore resulting in 200 sampling points. The EEG recordings were performed on subjects in a prone position, during relaxed but alert wakefulness, with eyes closed. The monopolar EEG derivations were measured with Ag/Agcl surface electrodes fixed at the positions C_3, C_4, F_3, F_4, P_3, and P_4, according to the international 10-20 electrode placement system. The raw EEG power spectra of each hemisphere were averaged for successive 10-sec period in all subjects for both the before and exposure conditions. The EEG asymmetry was calculated by comparing the power values in each frequency band from left and right hemispheres as a ratio. For quantitative assessment of these spectra, the mean spectral power density was calculated in distinct frequency range : Δ (1-3.5Hz), Θ (3.5-7.5Hz), α (7.5-12.5Hz), and β (12.5-8.0Hz). Statistical analysis was based on these spectral parameters. Differences were considered statistically significant at a P value(0.05) using the t-test

■ Results and Discussion

Figure 1 shows the spectral power densities in electrode placement is located in right parietal lobe during the recording session under among non-user, long-term-using user, and short-term-using user. This result is likely that statistical comparison of the data among long-term-using user, short-term-using user, and non-user exposure to the radiofrequency revealed no significant difference either for the alpha frequency range(7.5-12.5Hz) of for the EEG derivation. Public concern has increased about the possible health risks associated with exposure to ELF-EMFs and Radiofrequency. In this paper, we presented results indicating that quantitative recording of electroencephalograms(EEG) test was undertaken to examine the difference of the detection of function alteration of the central nervous system among non-using, long-term-using, and short-term-using group of the handheld cellular telephones. Further study should provide information on the contribution of various sources and the relationship between immune system activity / brain function and handheld cellular telephones in individual differences. The detailed results will be discussed at the meeting.

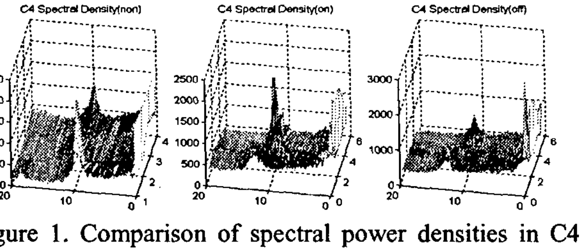

Figure 1. Comparison of spectral power densities in C4 during the recording session under among non-user(left), long-term-using user(middle), and short-term-suing user(right) conditions.

■ Acknowledgement

This study was supported in part by Grant of the Health Technology Planning & Evaluation Board, Ministry of Health & Welfare, Republic of Korea (01-PJ6-PG5-01P15-0001)

THE FREQUENCY-DEPENDENT EFFECT OF EXTRALOW FREQUENCE EMF ON THE GROWTH AND DIVISION OF *E.Coli*

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■ Introduction

Depending on the frequency, intensity and other characteristics EMF have stimulating or depressing effect on the growth and division of microorganism[1]. However, the mechanism by which the magnetic fields effects affect bacteria cell is not clear yet. As water is the basic component of living system it is suggested that EMF biological effect is realized through water structure changing[2]. To check this hypothesis the effect low frequency (LF) 12mT EMF-treated nutrient medium on microbes' growth and division was studied.

■ Observations

Previously it was shown, that E.coli K-12 *lon* mutants is very sensitive to various physical and chemical factors[3]. That's why it was chosen as an experimental model in the present study. The mutant culture was treated by 12 mT EMF of different frequencies for 30 min. It was found that LF EMF causes frequency dependent inhibition of cell division (Fig. 1). Similar effects were observed when EMF-treated nutrient medium was inoculated with untrea % mutant cells. At 4Hz EMF exposed nutrient medium 20% of cells survived, while in the case of 50Hz the survival increased up to 53%.

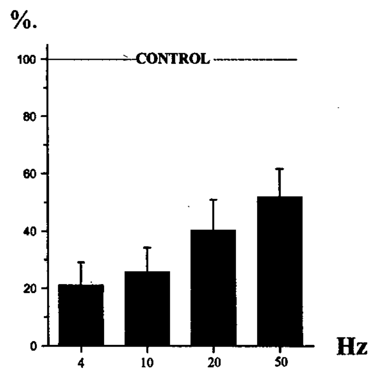


Fig. 1. Quantity of E.coli lon- HM9 mutant cells able to form macrocolonies under the influence of EMF

At all the frequencies of EMF treatment the cells lost their capacity to divide and to grow as filaments, i.e. unable to form colonies on the solid media.

The microscopic study of microbe cultures showed that significant number of cells treated by EMF lost their ability to divide and formed long filaments (Fig. 2). These filaments were much longer than the ones in control.

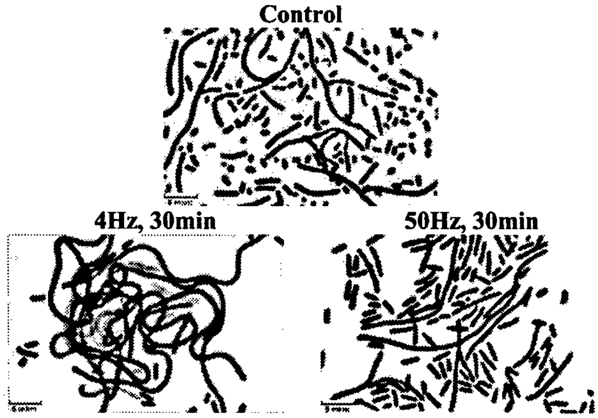


Fig. 2. Morphology of E.coli lon⁻ HM9 mutant cells treated by EMF.

■ Conclusion

The performed investigation demonstrated that EMF leads to frequency dependent inhibition of the growth and division of *Escherichia coli K-12 lon⁻* mutant cells. The effect of EMF treated nutrient medium was similar to the one observed in the case of the exposure of microbes themselves. The obtained data are interpreted from the point of the factor-induced water structure changes of cell bathing aqua solutions.

1. Alaverdyan Zh. R. *et al.*, Microbiology (Russian), 65 (2), 241-244, 1996.
2. Ayrapetyan *et al.* Bioelectromagnetics, 15, 133-142, 1994.
3. Ayrapetyan *et al.*, Microbiology. 70(2), 248-252, 2001.

Slide Presentation

International EMF Project

Dr MH Repacholi
Co-ordinator, Occupational and Environmental Health
World Health Organization, Geneva, Switzerland

WHO/ICNIRP/South Korean Government meeting
EMF biological effects and standards harmonization in Asia and Oceania
22-24 October 2001

Issues to be discussed

- ➔WHO's role in EMF
- ➔Scope and structure of the project
- ➔How WHO arrives at its recommendations
- ➔Update on activities and outputs
- ➔Recommendations to Member States
- ➔Information provided by Project

Scope and time scale

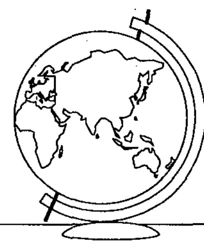
- ➢EMF Project established 1996 end in 2005?
- ➢EMF frequencies 0 to 300 GHz.
- ➢Static fields (0 Hz): Magnetic levitation trains, MRI imaging, DC electrolytic devices for materials processing in industry.
- ➢Extremely low frequency (ELF) fields (>0 to 300 Hz): Trains for public transport (16 2/3 to 50 or 60 Hz, plus harmonics), any device using electric power (normally 50 or 60 Hz).
- ➢Intermediate frequency (IF) fields (>300 Hz to 10 MHz): Anti-theft and security devices, induction heaters and VDTs
- ➢Radiofrequency (RF) fields (>10 MHz to 300 GHz): Mobile telephones or telecommunications transmitters, radars, video display units and diathermy units.

Collaboration

- International partners
  WHO, UNEP, ICNIRP, ILO, IEC
  IARC, NATO, ITU & EC
  - National partners >45
    - WHO collaborating institut
      USA, UK, Japan, Sweden &
      Germany
    - Independent scientific institutions

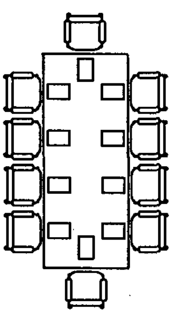
International Management

An International Advisory Committee has been established from representatives of the international and national collaborating agencies, and WHO collaborating institutions.

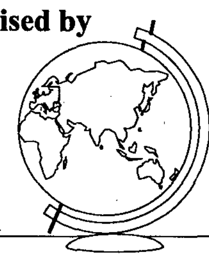


International Advisory Committee

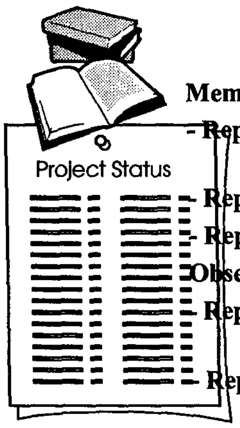
Terms of Reference



- **Provide oversight on the conduct of the Project.**
- **Review Project outputs**
- **Provide a forum for a co-ordinated international response on the health concerns raised by exposure to EMFs.**
  - Biological effects
  - Health issues
  - Use of precautionary measures
  - Standards



INTERNATIONAL ADVISORY COMMITTEE
Membership



Members:
- Representatives of governments providing resources for Project
- Representatives of scientific collaborating organizations
- Representatives of WHO collaborating centres

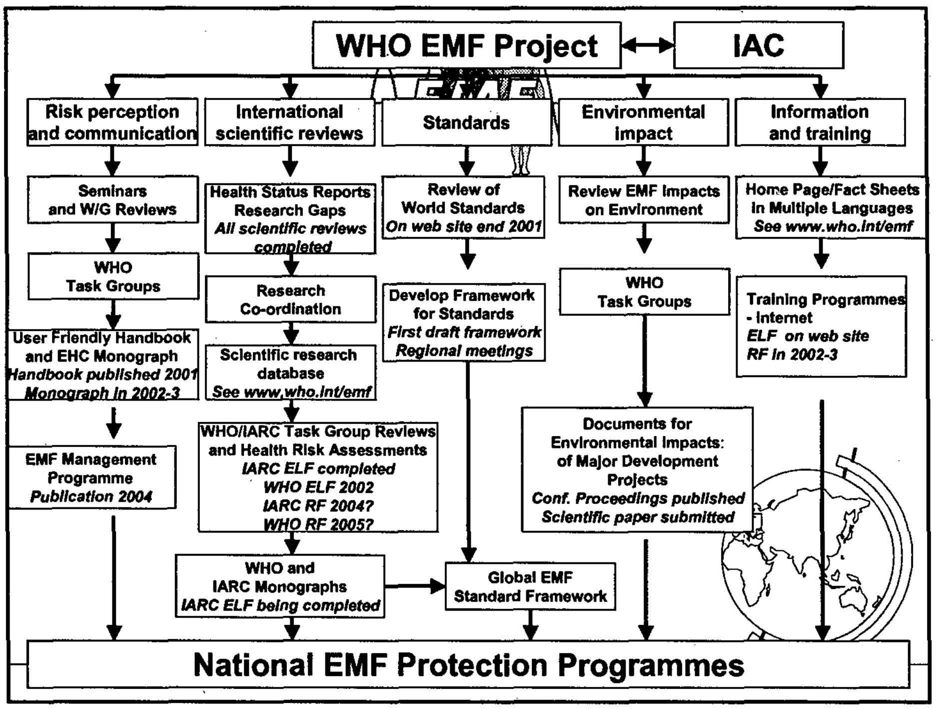
Observers:
- Representatives of governments interested in supporting Project
- Representatives of independent scientific bodies

Role of WHO staff in EMF Project

➔Facilitate the implementation of the programme agreed to by the International Advisory Committee
➔Form part of the non-voting secretariat at all meetings and expert groups
➔Compile minutes, fact sheets and reports of meetings published after comments by IAC and outside experts
➔Give presentations summarising the conclusions of WHO meetings or expert groups
➔Must ensure compliance with WHO's conflict of interest policies (Committee membership, funding, etc)

International EMF Project

- provides forum for co-ordinated international response to EMF issues
- assesses scientific literature; makes status report on health risks
- identifies gaps in knowledge needing research to make better health risk assessments
- encourages focused research program
- Evaluates research results and publishes as WHO monographs
- Develops framework for an international standard
- Uses health risk assessments to facilitate internationally acceptable standards for EMF exposure



WHO approach to EMF research for health risk assessment

- Develop "best possible" database needed by WHO/IARC to assess health hazards?
- Review literature to identify research to fill gaps
- Replicate research suggestive of health consequence but not substantiated
- Promote research agenda to funding agencies

What are we trying to protect against?

Biological and Health Effects

- WHO defines health as a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity
- Biological effects are measurable responses to EMF exposure ....not necessarily hazardous
- Health hazard is a biological effect producing consequences outside the body's normal range of physiological compensation and is detrimental to health or well-being
- *Problem:* the public and media do not discern between biological and health effects

Recommendations to Member States

EMF Protection of the Public

Recommendations to Member States

Address Health Issue

Mandatory science-based standards

Address Public Concerns

Separate policy of voluntary precautionary measures

Introducing ad hoc additional safety factors into science-based standards as a precautionary measure undermines 100's of millions of $s of research for no apparent benefit to health

Questions raised....are the safety factors in international standards large enough to address the imprecision in the science? How uncertain is the science?

Voluntary measures

- **Governmental/industrial/academic research program that leads to better health risk assessments**
- **Encourage manufacturers to keep exposures to the minimum needed for the technology**
- **Better risk communication**
  - **Target messages to audience**
  - **Honest and accurate information**
- **Public involvement in decision-making**
- **Siting facilities to minimise public exposure and concerns**

EMF Project **WHO Fact Sheets**

- The International EMF Project. Fact Sheet #181, Oct 1997
- Physical properties and effects on biological systems. Fact Sheet #182, Oct 1997
- Health effects of radiofrequency fields. Fact Sheet #183, Oct 1997
- Public perception of EMF risks. Fact Sheet #184, Oct 1997
- Mobile telephones and their base stations. Fact Sheet #193, June 2000
- Video display Units (VDUs) and human health. Fact Sheet #201, July 1998
- Extremely low frequency electromagnetic fields. Fact Sheet #205, Nov 1998
- Radars and Human Health. Fact Sheet #226, June 1999
- Cautionary Policies (WHO Backgrounder), March 2000
- *ELF fields and cancer Fact Sheet #263, October 2001*
- Environmental Hypersensitivity (in draft)
- EMF Environmental Impacts (in draft)
- Intermediate Frequencies (in draft)
- Protection of the Public from EMF (in draft)

On home page: http://www.who.int/emf/ in multiple languages

Further information

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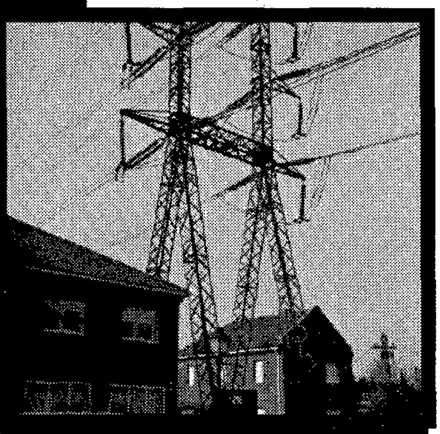
REVIEW OF ANIMAL STUDIES

Bernard Veyret

Not Available



EMF Epidemiology:
State of the Science

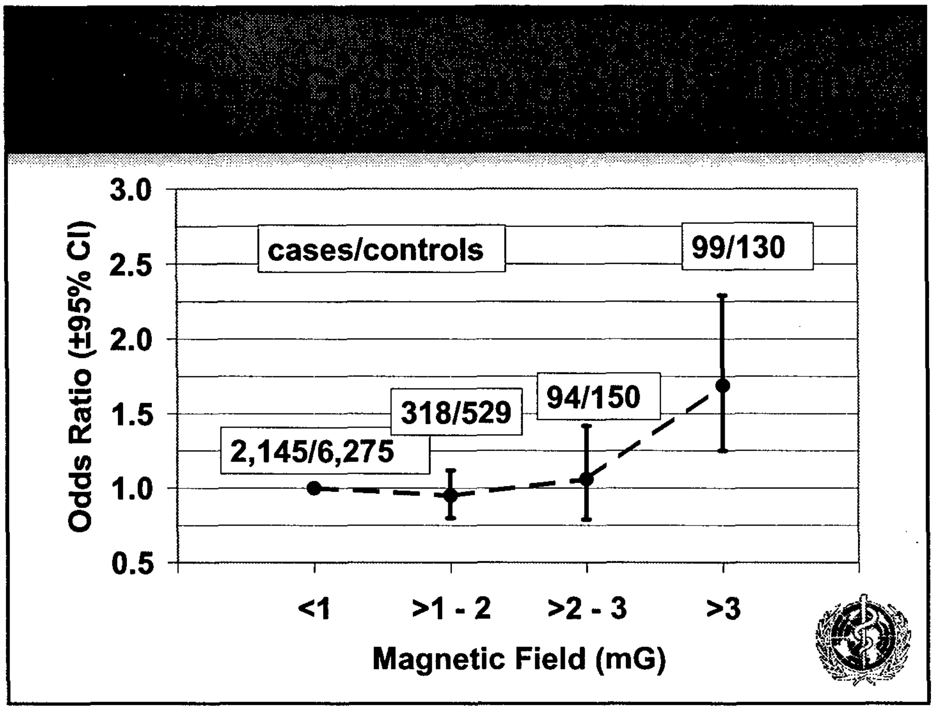
Dr Leeka Kheifets
Head, Radiation Program
World Health Organization
Switzerland

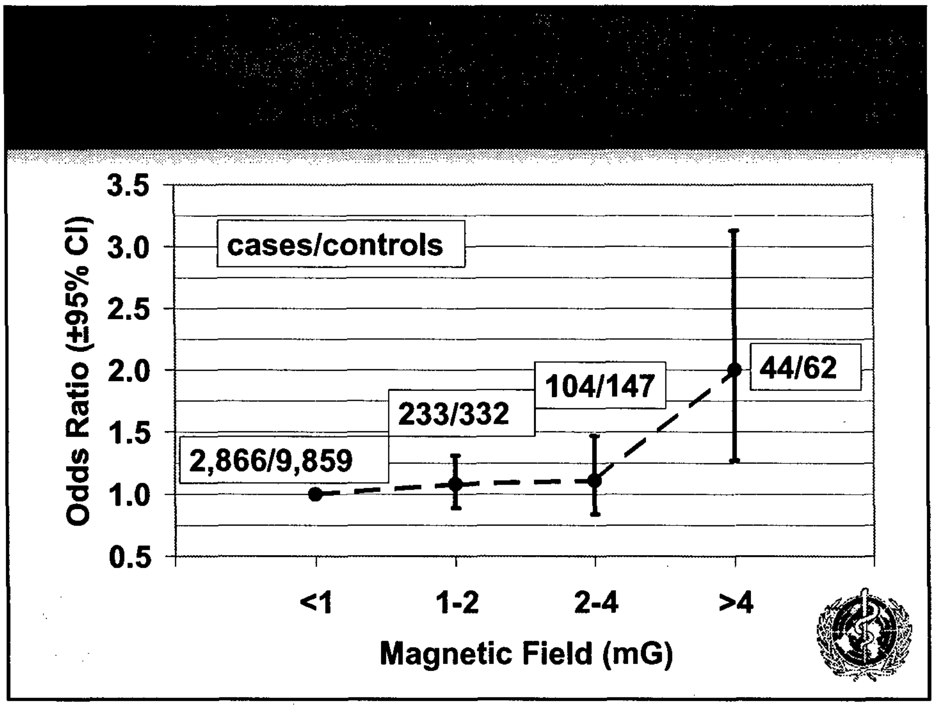
WHO Meeting on EMF Biological Effects and Standards Harmonization in Asia and Oceania
Seoul, South Korea
22-24 October 2001

- Driving the issue: leukemia and brain cancer
- New: breast cancer, neurodegenerative and heart disease
- Almost not a question: reproductive outcomes
  - CDHS studies?

- Residential
  - Wire code
  - Measurements
- Occupational
- Appliance use

- Greenland et al., *Epidemiology*, 2000
  - 12 studies with fields; 4 with wire codes
  - Not including UK study
  - Field studies: 2,656 cases; 7,084 controls
  - Metric of choice: time-weighted average
- Ahlbom et al., *British J. Cancer*, 2000
  - 9 studies with fields; 2 with wire codes
  - Including UK study
  - Field studies: 3,247 cases; 10,400 controls
  - Metric of choice: geometric mean


cases/controls
99/130
318/529
94/150
2,145/6,275
Odds Ratio (±95% CI)
3.0
2.5
2.0
1.5
1.0
0.5
<1
>1 - 2
>2 - 3
>3
Magnetic Field (mG)


cases/controls
104/147
44/62
233/332
2,866/9,859
Odds Ratio (±95% CI)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
<1
1-2
2-4
>4
Magnetic Field (mG)

Summary OR	≤ 0.1μT (ref.)	>0.1μT, ≤ 0.2μT	>0.2μT, ≤ 0.3μT	>0.3μT
Without covariate adjusment				
Woolf	1.00	1.00 (0.82 – 1.21)	0.98 (0.68 – 1.40)	1.91 (1.37 – 2.67)
Mantel-Haenszel	1.00	0.98 (0.82 – 1.19)	0.96 (0.67 – 1.36)	1.69 (1.21 – 2.35)
Spline	1.00	1.04 (0.93 – 1.17)	1.21 (1.02 – 1.43)	1.83 (1.14 – 2.93)
With covariate adjustment				
Woolf	1.00	1.08 (0.87 – 1.35)	0.97 (0.65 – 1.44)	2.14 (1.49 – 3.08)
Mantel-Haenszel	1.00	1.03 (0.81 – 1.31)	0.87 (0.55 – 1.37)	2.22 (1.48 – 3.34)

Greenland et al., 2000

Exposure	Relative Risks (95% Confidence Intervals)		
	Measurement	Calculated Fields	All Studies
<0.1 μT	1.00	1.00	1.00
0.1 - 0.2 μT	1.05 (0.9 - 1.3)	1.58 (0.8 - 3.3)	1.08 (0.9 - 1.3)
0.2 - 0.4 μT	1.15 (0.9 - 1.5)	0.79 (0.3 - 2.3)	1.11 (0.8 - 1.5)
>0.4 μT	1.87 (1.1 - 3.2)	2.13 (0.9 - 4.9)	2.00 (1.3 - 3.1)

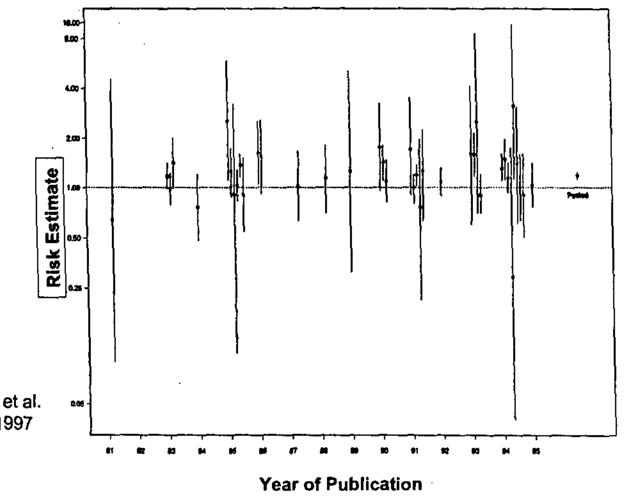
Ahlbom et al., 2000

Conclusions: Pooled Analysis

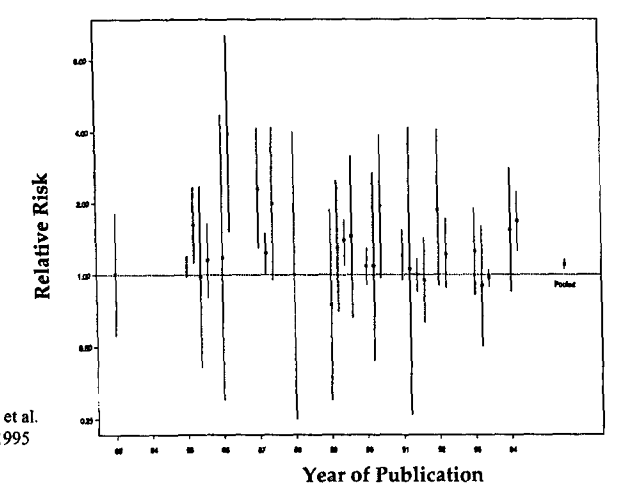
- ≈ 2-fold increase in risk above 0.3 - 0.4 µT
- Association more consistent with measured fields than with wire codes
- Attributable fraction estimate ≈ 3%
- No confounding evident
- Selection bias may be a partial explanation
- Unlikely to be due to random variability

Childhood Leukemia Summary

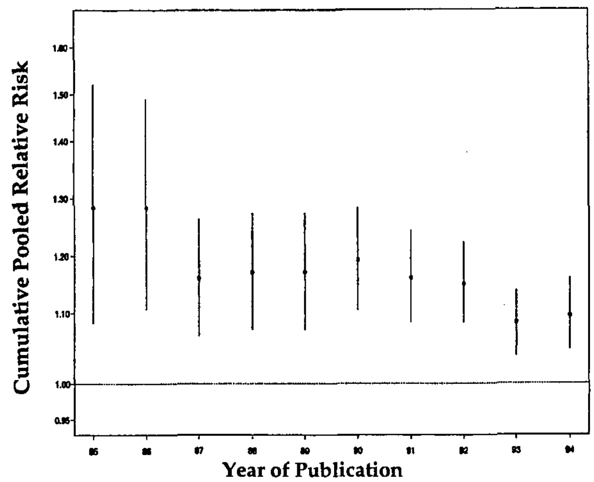
- Childhood leukemia main driver in risk assessments
- Recent pooling efforts point to risk at 0.3 - 0.4+µT
- Animal studies negative
- Ongoing studies
  - Germany, Italy, Japan, U.S., UK
- Research needs:
  - High-exposure studies
  - Contact currents
  - Population mixing
  - Transients
  - Selection bias



Kheifets et al.
JOEM, 1997



Kheifets et al.
JOEM, 1995



Kheifets et al.
JOEM, 1995

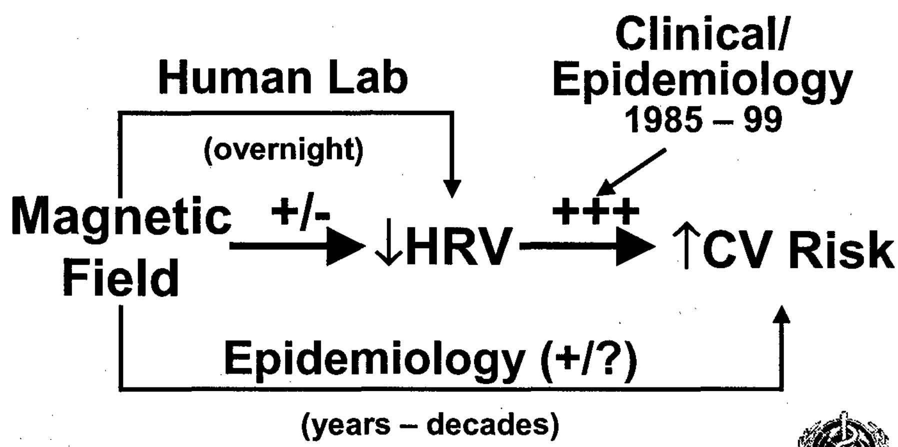
- Small risk at the limit of detection
- Few to no studies under way
- Research needs:
  - Exposure assessment based on job *and* environment
  - Electric fields
  - Combining residential and occupational exposure
  - Contact current exposure assessment

- Major women's health (& public health) issue
- Tied (rightfully or wrongfully) to EMF, based mainly on prior laboratory research
- Hypothesis-based

?
?

- Epidemiologic studies largely negative
  - None designed to test the hypothesis

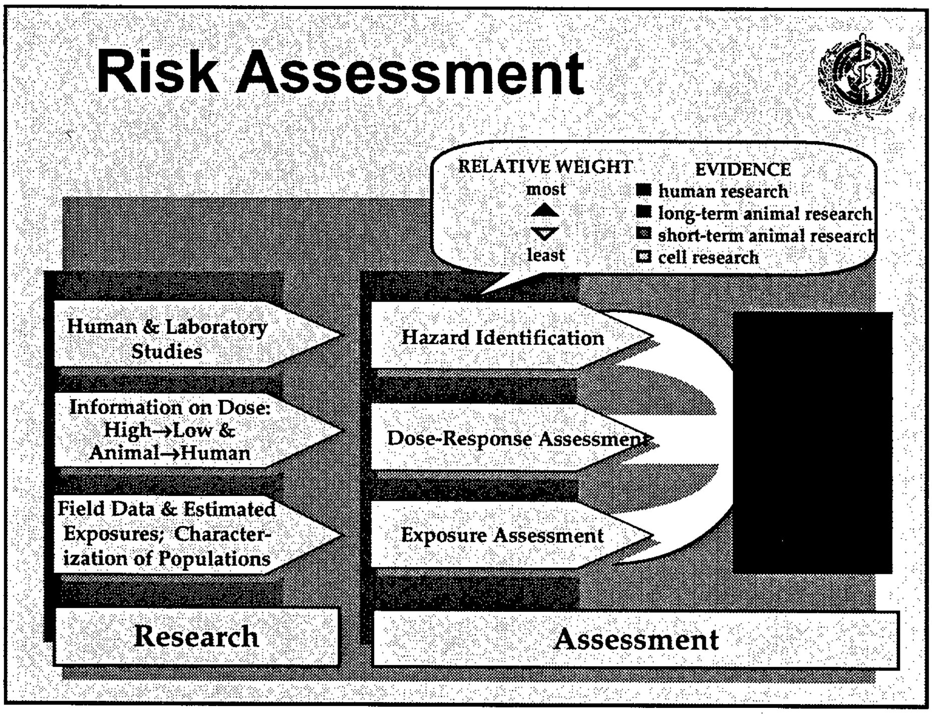
- Animal studies inconsistent
  - German results not replicated in the U.S.
- MC-7 cells
  - Effect seen only in certain type of cells
  - Replicated in 3 to 4 laboratories
  - Extremely low exposures



- Association with acute mortality reported in one study
- HRV reduction in laboratory setting apparently inconsistent
- Two analyses of existing data under way
- Research needs:
  - Cardiovascular cause-of-death misclassification on death certificates

- Increasingly geriatric population
- Suggested risks associated with occupational electrical factors (e.g., jobs, shocks)
- No prior studies specifically designed to examine EMF
- Little ongoing work
- Research needs:
  - Strong methodologic studies looking at electric shocks and other EMF exposures

- Overall negative epidemiologic and laboratory work
- Two recent analyses point to exposures not previously looked at
- Research needs:
  - Evaluate new data



- Initiated in 1969
- Criteria established in 1971, last update 1992
- Limited largely to the first step in risk assessment
- "Carcinogen": exposure that is capable of increasing the incidence of malignant neoplasms (at any stage of the carcinogenesis)
- No recommendation is given with regard to regulation of legislation, as they are the responsibility of governments or other international organizations
- EMF - Volume #80
- 800+ agents have been evaluated

- For each disease classify human and animal data separately as:
    - Sufficient
    - Limited
    - Inadequate
    - Lack of effect

- Integrate the two classifications above (*in vitro* as support):
    - Is carcinogenic to humans (Group 1)
    - Probably is carcinogenic to humans (Group 2A)
    - Possibly is carcinogenic to humans (Group 2B)
    - Not classifiable (Group 3)
    - Is probably not carcinogenic to humans (Group 4)

A positive association has been observed between exposure to the agent, mixture or exposure circumstance and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence.

Classification	Examples
Carcinogenic to humans (75) *(usually based on strong evidence of carcinogenicity in humans)*	Asbestos Mustard gas Tobacco (smoked and smokeless) Gamma radiation
Probably carcinogenic to humans (59) *(usually based on strong evidence of carcinogenicity in animals)*	Diesel engine exhaust Sun lamps UV radiation Formaldehyde
Possibly carcinogenic to humans (225) *(usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)*	Coffee Styrene Gasoline engine exhaust Welding fumes

Tasks

- Ascertain that all appropriate data have been collected
- Select data based on scientific merit
- Prepare accurate summary to enable reader to follow the reasoning
- Evaluate results of epidemiologic and experimental studies
- Evaluate data relevant to mechanisms of action
- Make overall evaluation of carcinogenicity to humans

Membership

- 23 participants
- Expertise: epidemiology, toxicology, biology, biophysics, statistics, risk assessment, exposure assessment
- 11 countries

- ELF MAGNETIC FIELDS classified as Group 2B "Possible Carcinogenic"
  - based on epidemiologic studies of childhood leukemia
  - animal data inadequate
- Other exposures and outcomes considered "inadequate to classify"

- Populations near antennas and base stations (including cluster studies)
- Occupational/Military personnel studies
- Cell phone users

- Number of calls and call duration
- Power level of cell phone
- Left- or right-hand use
- User positioning of phone at the face
- Phone type / model

- Mostly studies of clusters next to transmitters
- Focus on leukemia; other cancers include brain and bladder cancer and skin melanoma
- Inconsistent results with few statistically significant findings (childhood leukemia?)

- Ecologic fallacy
- Small numbers
- Previously identified clusters
- Potential confounding
- Exposure assessment, exposure assessment, exposure assessment

- Few cohort and case-control studies
- Outcomes of interest: leukemia and brain cancer (other outcomes include uveal, testicular, breast and lung cancer)
- Inconsistent, unreplicated results for various cancer types

- Job title classification
- Lack of measurements
- Lack of control for potential risk factors
- Use of external comparison groups

- Three case-control and two cohort studies of cell phone users
- Focus on brain cancer
- Results negative
  - Hints of location of tumor and handedness

- Crude assessment
- No measurements
- Low usage (?)
- Short latency
- Hospital controls

- Similar:
  - High public awareness
    - Focus on involuntary exposure from powerlines and antennas .
  - Potentially large public health impact
  - Difficulties in exposure assessment exacerbated by unknown biophysical mechanism

ELF Studies

- Much more sophisticated exposure assessment
- More plentiful
- Addressing broader range of outcomes
- Somewhat more consistent

RF Studies

- Severely limited by exposure assessment which is likely to be even more difficult than for ELF
- Evolving technology
- Limited by latency
- Only a few outcomes examined (mostly cancer)
- Limited methodologically

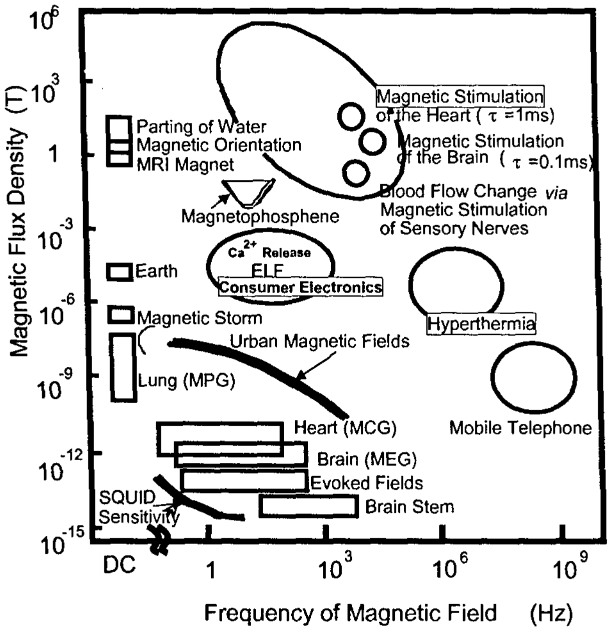
- Epidemiology
  - Large misclassification
  - Small risk
  - Lack of consistency
- Animal studies
  - Relevant exposure
  - Right model
  - Power to detect small risk
- In Vitro
  - Lack of robust effect
  - Replication
  - Relevance
- Integration
  - Multidisciplinary approach needed
  - Carcinogenesis is a complex and highly variable process

Mechanisms of Interaction of EMF

Shoogo Ueno

Department of Biomedical Engineering
Graduate School of Medicine
University of Tokyo, Tokyo 113-0033 Japan

1. **Introduction**
2. **Static magnetic fields**
3. **ELF and low frequency electromagnetic fields**
4. **Pulsed magnetic fields**
5. **Radio frequency electromagnetic fields**



Mechanisms of biological effects of electromagnetic fields

i) time -varying magnetic field

eddy currents	$J = -\sigma \frac{\partial B}{\partial t}$	**nerve stimulation**
heat	$SAR = \sigma \frac{E^2}{\rho}$	**thermal effects**

ii) homogeneous magnetic field

magnetic torque

$$T = \square \frac{1}{2\mu_0} B^2 \Delta\chi \sin 2\theta$$

magnetic orientation of biological cells

iii) inhomogeneous magnetic field

magnetic force

$$F = \frac{\chi}{\mu_0} (\mathrm{grad}\, B)\, B$$

parting of water by magnetic field (Moses effect)

iv) effect of magnetic field on photochemical reactions

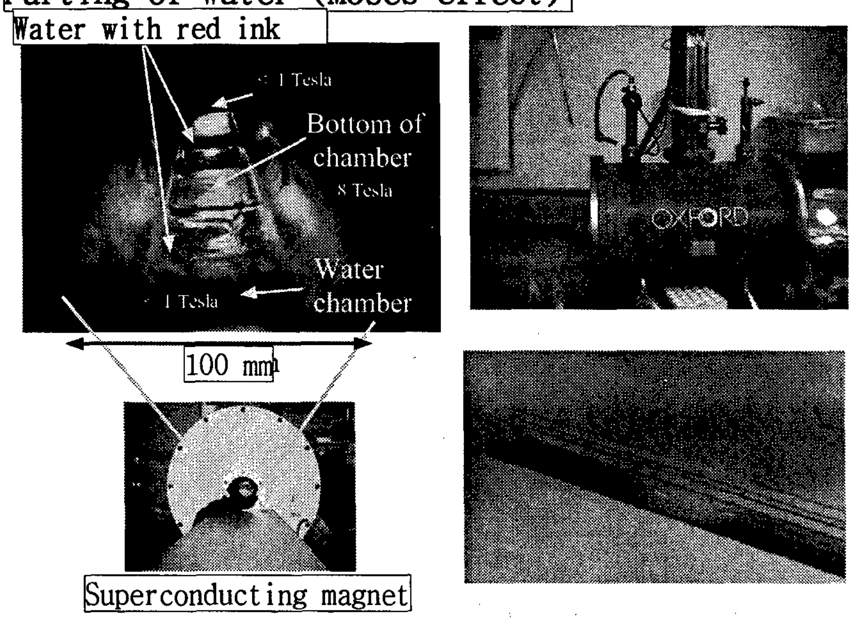
radical pair model

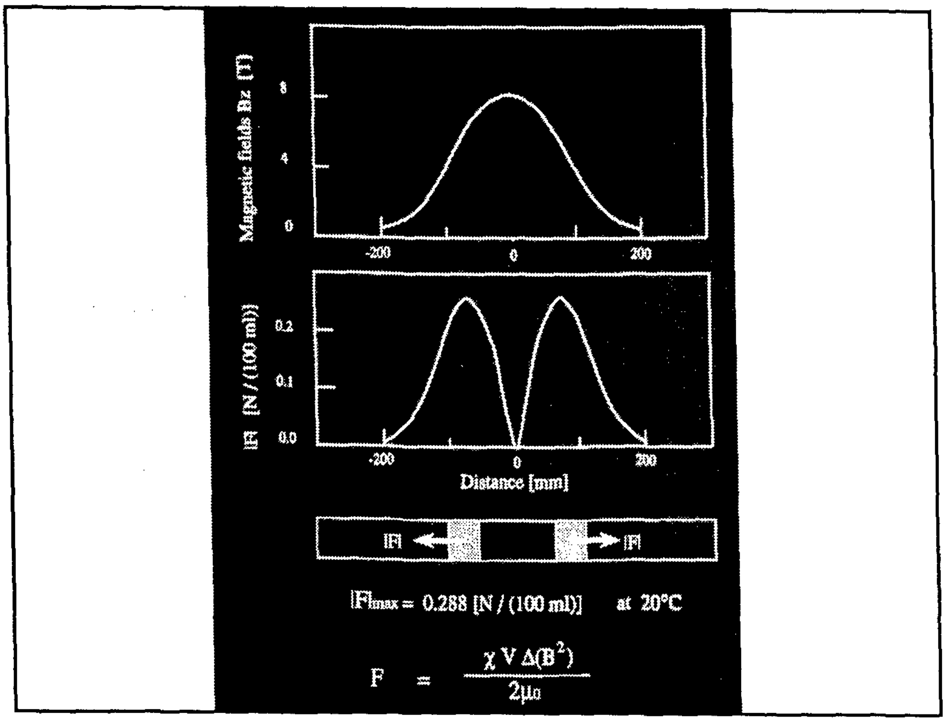
yield effect of cage -product and escape -product

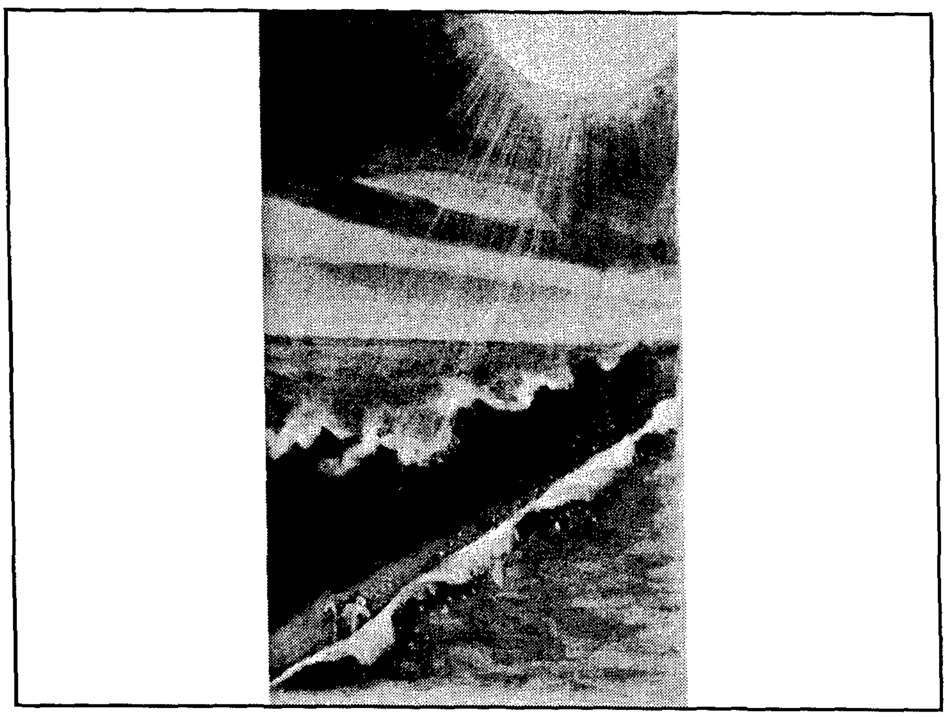
Static magnetic fields

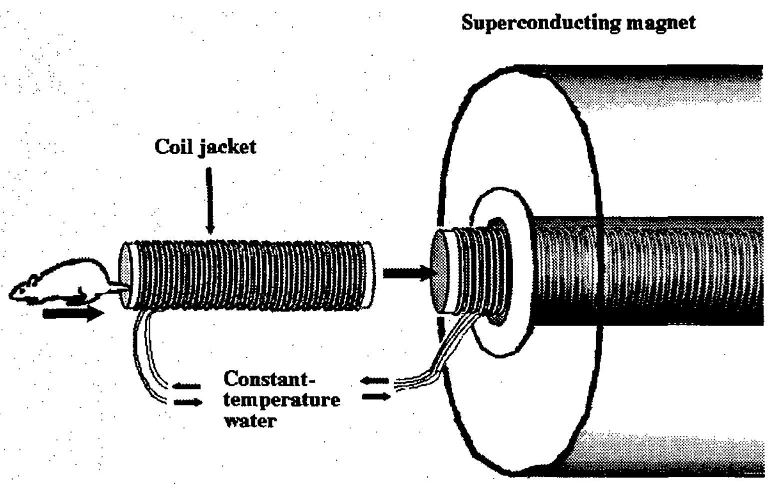
1. Diamagnetic materials
   water, fibrin, collagen, cells, oxy-hemoglobin
2. Paramagnetic materials
   oxygen, deoxyhemoglobin
3. Ferri- or Ferro-magnetic materials
   magnetite Fe_3O_4

Parting of Water (Moses effect)

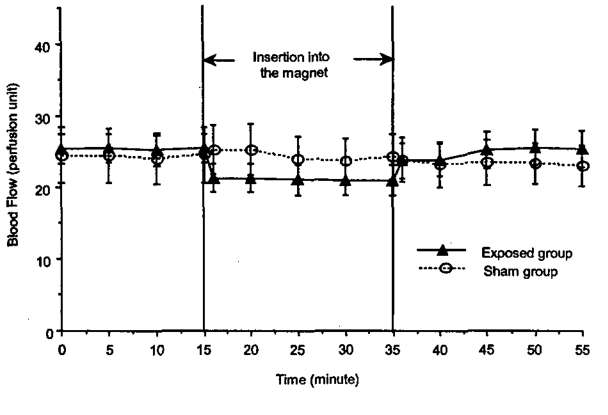



Magnetic fields Bz [T]
8
4
0
-200
0
200
|F| [N / (100 ml)]
0.2
0.1
0.0
-200
0
200
Distance [mm]
|F|
|F|
|F|max = 0.288 [N / (100 ml)] at 20°C
$F = \frac{\chi V \Delta(B^2)}{2\mu_0}$

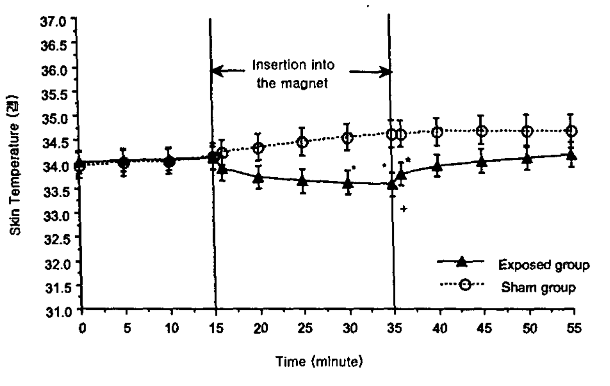




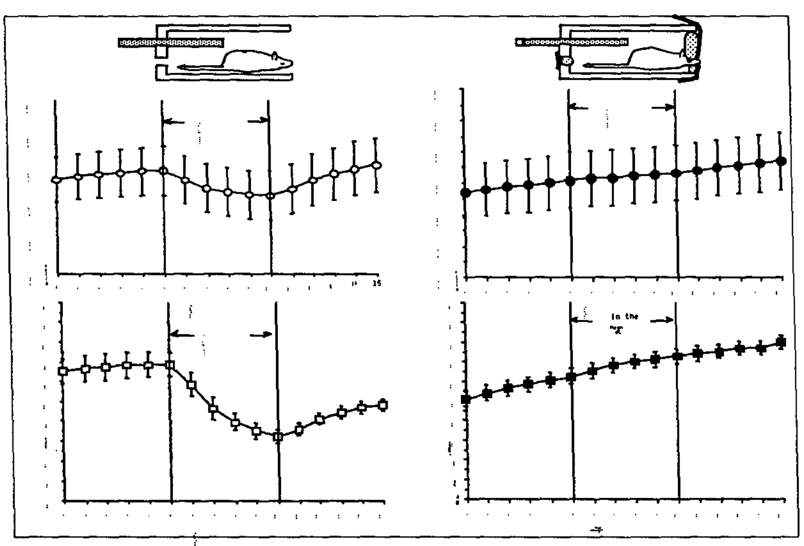
The animal is exposed to magnetic field under controlled temperature.



Changes in blood flow measured by laser Doppler flowmeter.



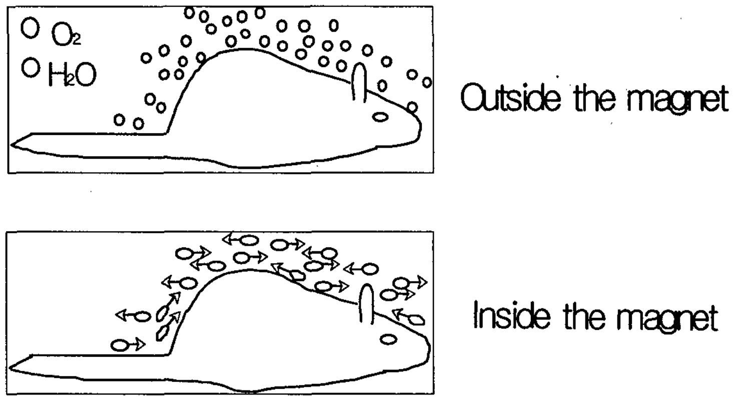
Changes in skin temperature.

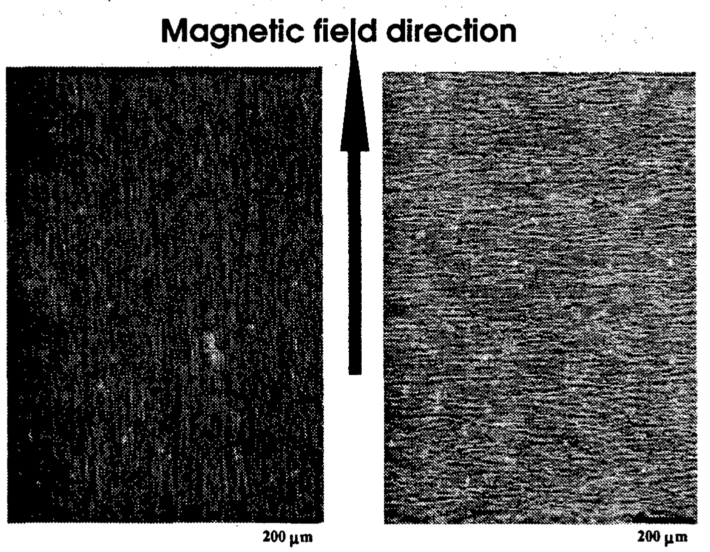


Group I Open holder

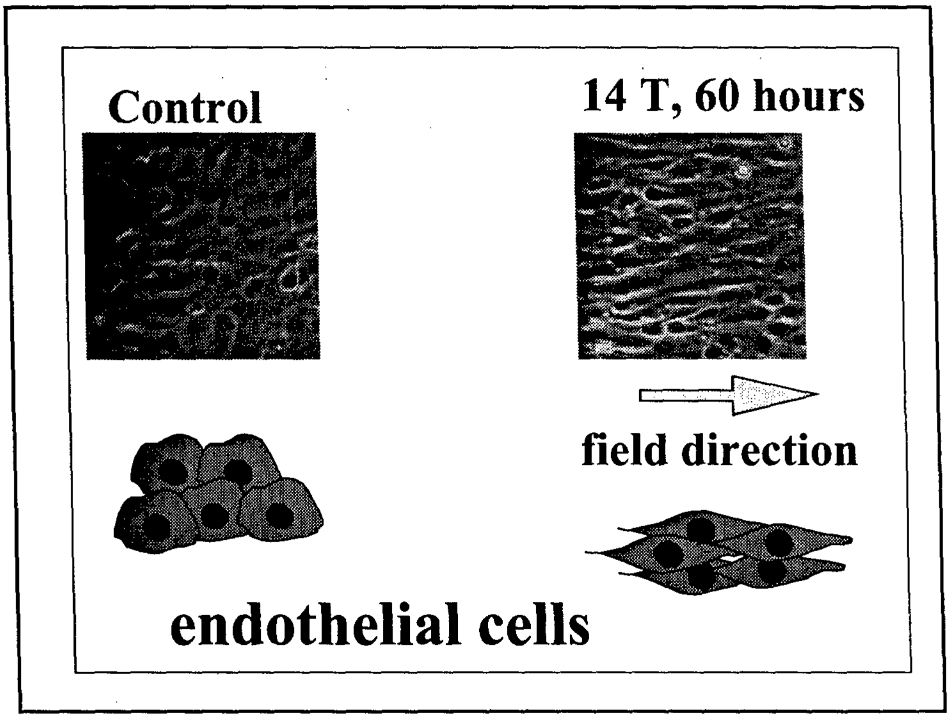
Group I I Closed holder

Hypothesis of the mechanism of skin-temperature change





(a) Fibrin (b) Collagen



Magnetic Orientation

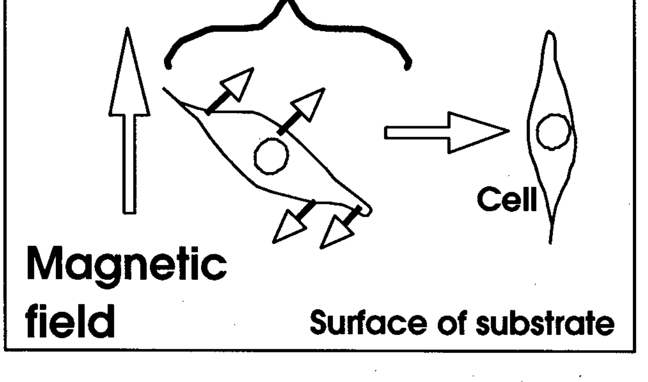
- Fibrin fibers
- Collagen
- Erythrocytes
- Platelets
- Smooth muscle cells
- Endothelial cells
- Osteoblasts
- Others

Magnetic anisotropy

- π electron in benzene
- lipid bilayer
- α - helix composed of peptides
- etc.

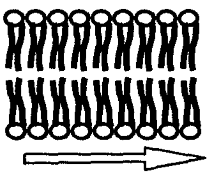
Magnetic orientation

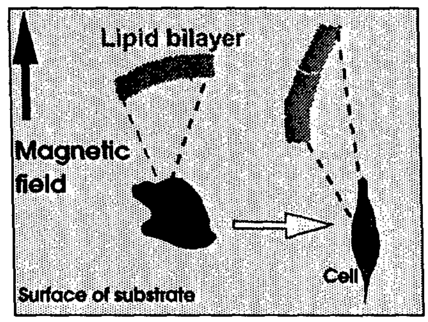
Torque forces on cell components (membrane, actin-filament, etc.)

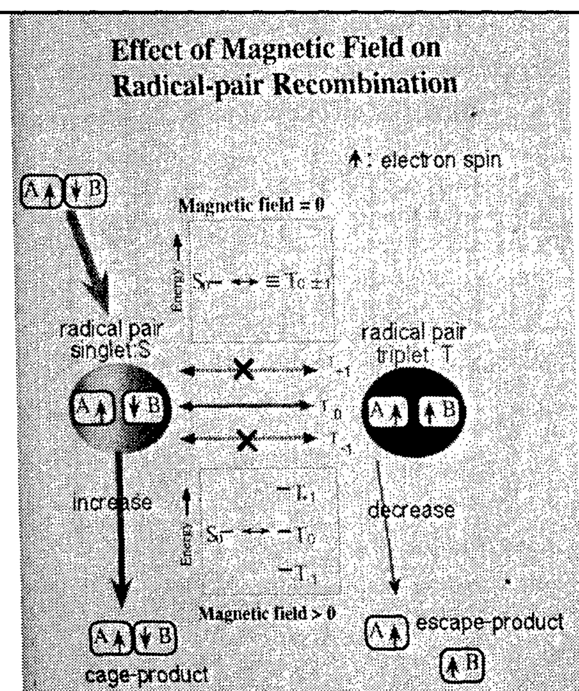


Magnetic deformation

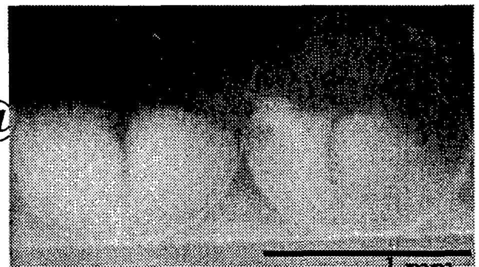
magnetic deformation of cell membrane





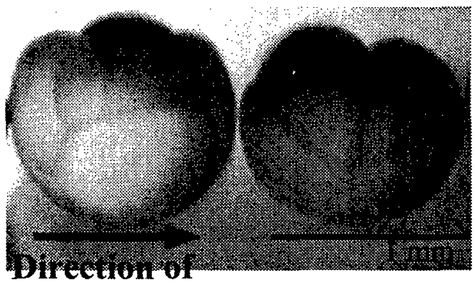


Control □@
,OTesla



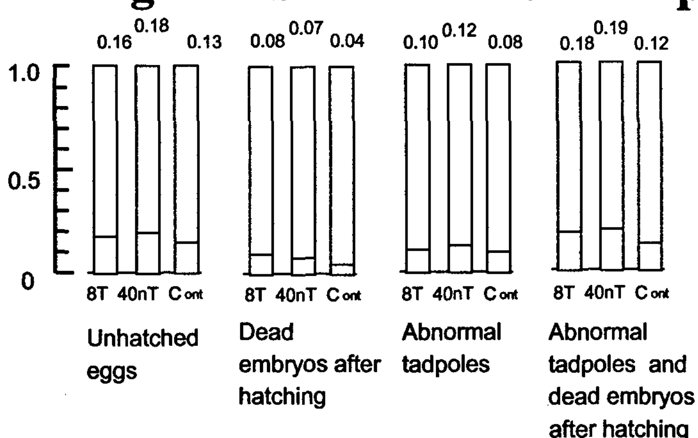
Effect of magnetic field on the cleavage pattern of frog's egg

1st ~ 3rd cleavage
Magnetic field exposed
□@,STesla



Percentage of abnormalities in tadpoles

8 Tesla



Number of Samples		
	8T	289
	40nT	302
	Control	334

i) Embryonic development of Xenopus laevis-no apparent teratogenic effects after exposure to 8T magnetic fields for several hours.

ii) No enzymatic effects of catalase under 8T magnetic fields.

iii) Decrease in skin blood flow, body temperature, blood pressure, and heart rate of rats exposed to 8T for 20 min. Accelerated evaporation of moisture from the skin by magnetic fields.

iv) Magnetic orientation of collagen, fibrin, red blood cells, endothelial cells, and osteoblasts under 8T magnetic field exposure.

v) Parting of water by magnetic fields: Moses Effect at 8T, 50 T/m. (diamagnetic water)

vi) Blocking of gas flow by magnetic fields: Magnetic Curtain at 1T, 100 T/m. Quenching of combustion; quenching of burning candle flame by magnetic fields - 1.2T, 300 T/m. Magnetic curtain is formed by paramagnetic oxygen during exposure to magnetic fields.

vii) Redistribution of dissolved oxygen concentration by 8T, 50T/m.

ELF and low frequency electromagnetic fields

Time-varying magnetic field

Alternating-, Transient-, Pulsed-, Burst- magnetic field

Induced electric field: E [V/m]

Eddy current: J = σ E [A/m^2]

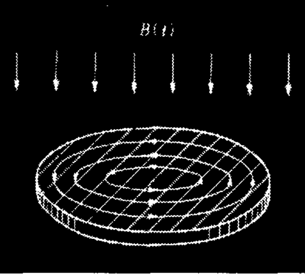
ELF	**Stimulatory effects:**
Low frequency	**Nerve excitation,**
Pulsed	**Muscle contractio**
	Non-stimulatory effects ?
High frequency	**Thermal effect: Heat SAR [W/kg]**
	Non-thermal effect ?

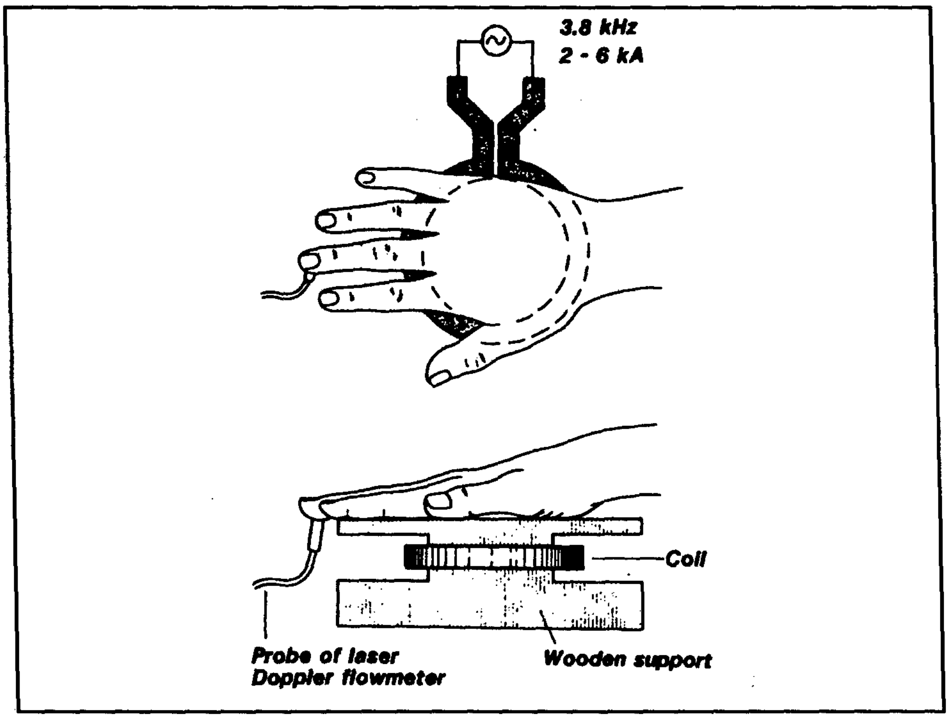
$$\nabla \times E = -\frac{\partial B}{\partial t}$$

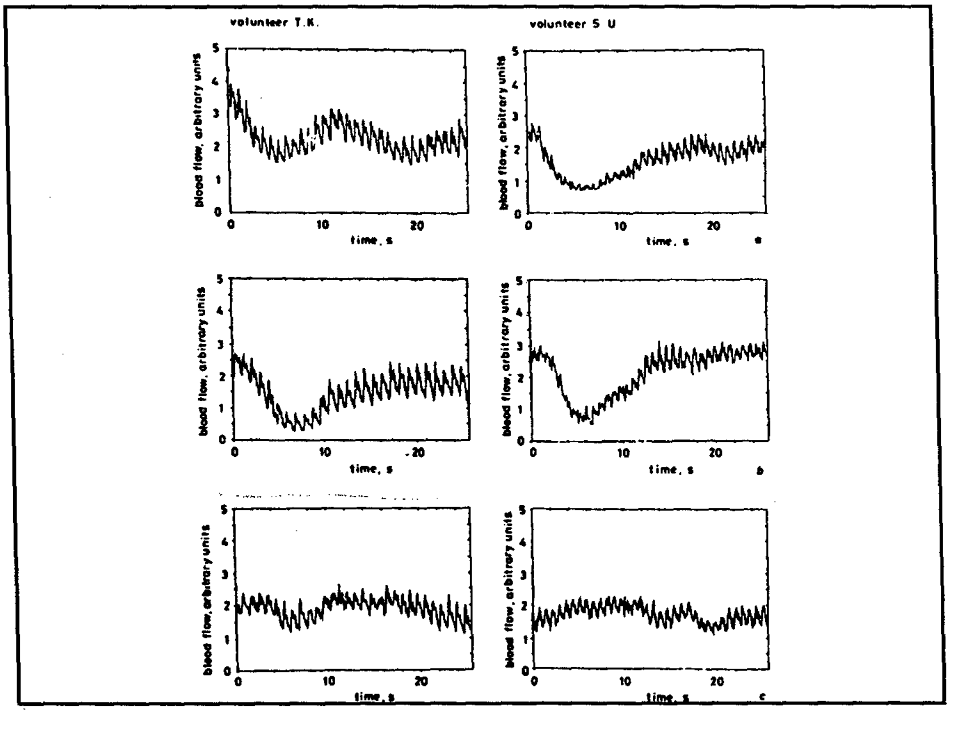
$$i = \sigma E$$

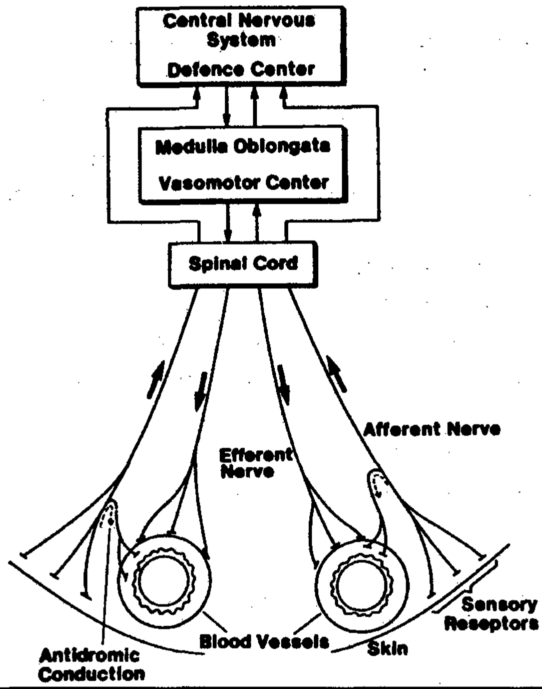
$$\nabla \times i = -\sigma \frac{\partial B}{\partial t}$$

$$\left.\begin{aligned}
\frac{\partial i_z}{\partial y} - \frac{\partial i_y}{\partial z} &= -\sigma \frac{\partial B_x}{\partial t} \\
\frac{\partial i_x}{\partial z} - \frac{\partial i_z}{\partial x} &= -\sigma \frac{\partial B_y}{\partial t} \\
\frac{\partial i_y}{\partial x} - \frac{\partial i_x}{\partial y} &= -\sigma \frac{\partial B_z}{\partial t}
\end{aligned}\right\}$$




3.8 kHz
2 - 6 kA
Coil
Probe of laser
Doppler flowmeter
Wooden support


volunteer T.K.
volunteer S U
blood flow, arbitrary units
time, s
a
b
c



Residential DC and ELF Magnetic Fields

Earth's Magnetic Field
20 – 50 μT DC

ELF Magnetic Fields
0.2 – 20 μT 50/60 Hz

There is no evidence of harmful health effects due to residential electromagnetic field exposure.

More extensive in vitro and in vivo studies are needed .

1. **Dosimetry and exposure systems**

2. **In vitro studies**
   Cell membrane and ion channeling
   Signal transduction, Proliferation, Mutation

3. **In vivo studies**
   Carcinogenesis, Immune system, Nervous system
   Endocrine system, Circulatory system,
   Reproduction, Developmental process

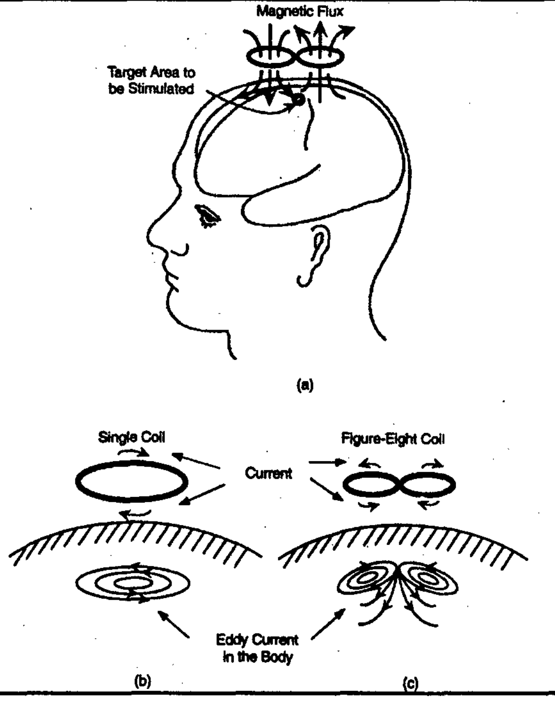
4. **Human studies**
   Neurophysiological effect, Sleep, Insomnia, Malaise

5. **Epidemiological studies**
   Brain tumor, Leukemia, etc.

Models and hypotheses

Membrane noise model
Chemical reaction rate modulation model
Calcium ion inflow model
Model of calcium ion binding to calmodulin
Cyclotron resonance model
Paramagnetic resonance model
Free radical model
Magnetite particle model related to pressure-sensitive ion channeling
Signal transduction models
Melatonin secretion and breast cancer hypothesis
□
□
□

Pulsed magnetic fields



Current Distributions on a Coronal Slice

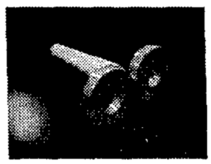
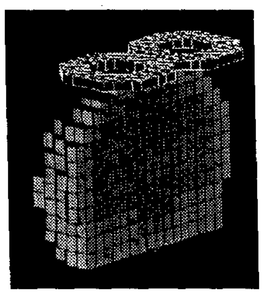


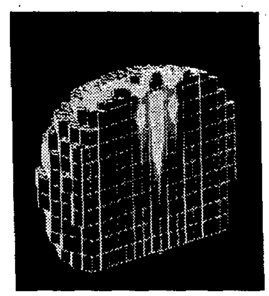
Figure-eight coil

Stimulus parameters

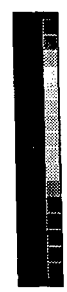
Total current in the coil □ 2000 [A]
Current density □ $1.2 \cdot 10^8$ [A/m²]
Magnetic flux density at the coil center □ 0.60 [T]
Waveform □ Continuous sinusoidal wave
Frequency □ 4.2 [kHz]



Coronal slice of the model



Current distributions

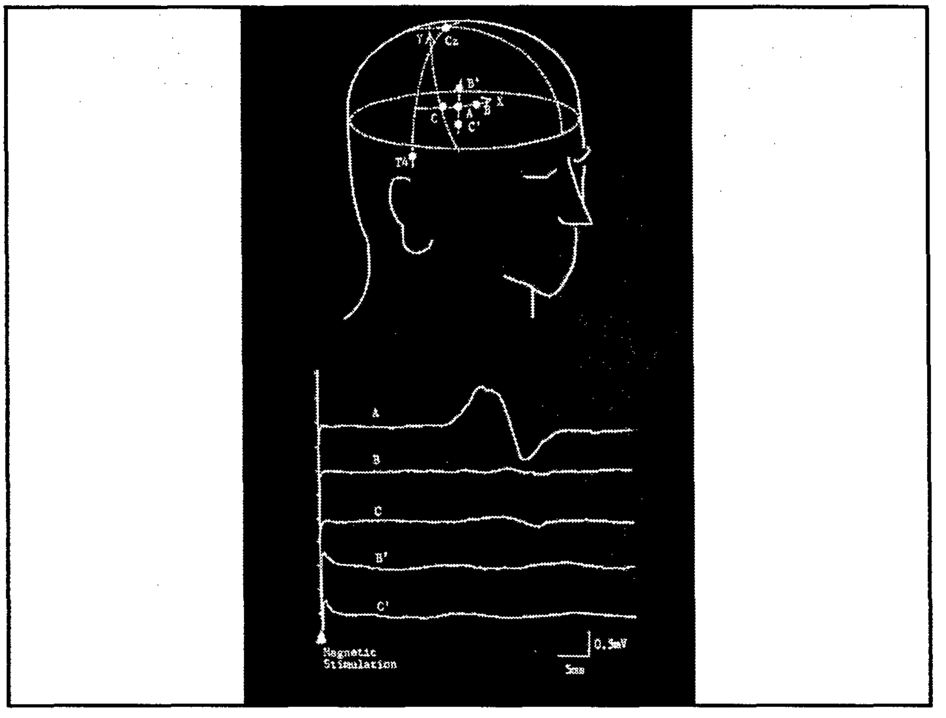


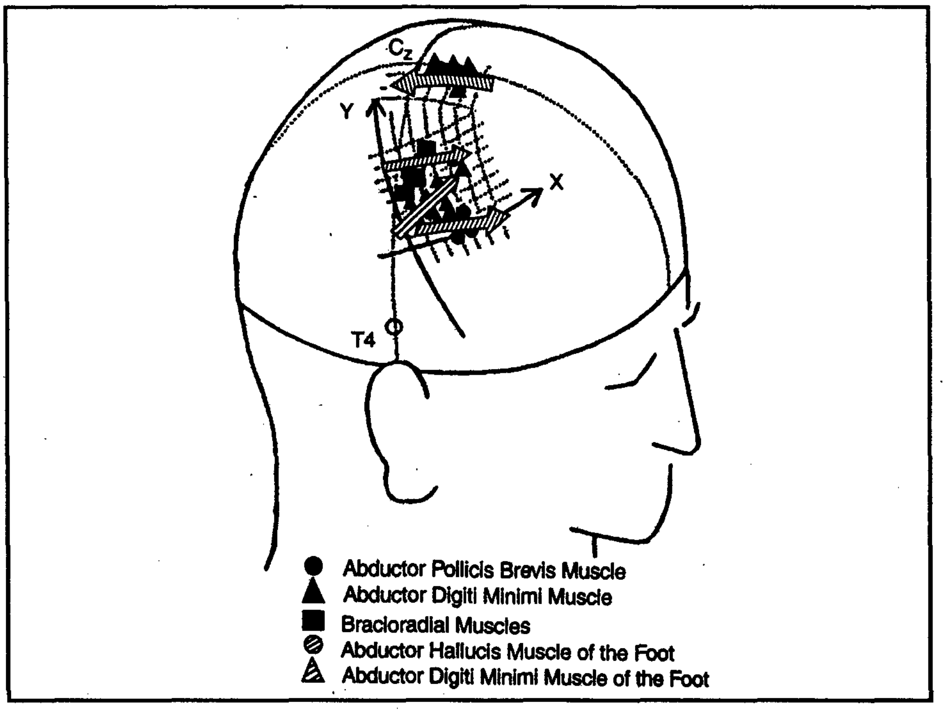
[A/m²]

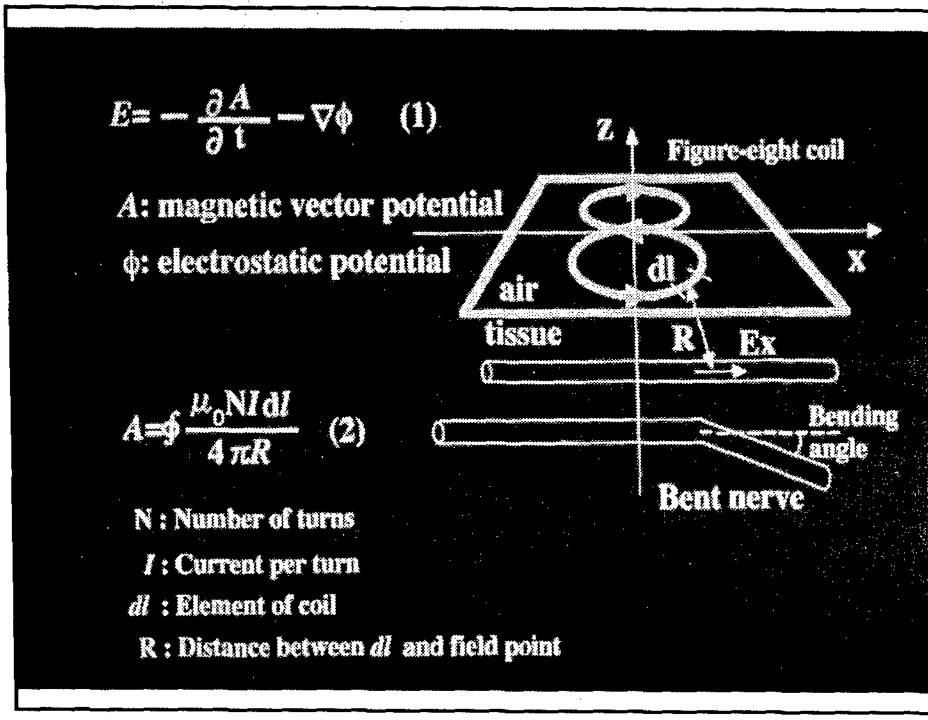
Maximum value in the scalp
393 [A/m²]

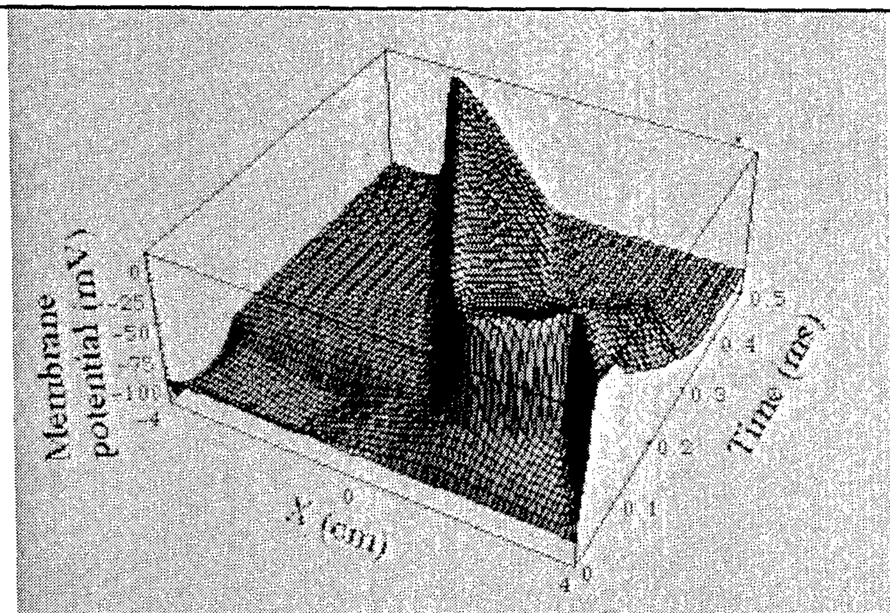
Maximum value in the brain
322 [A/m²]

Brain center
80 [A/m²]


Cz
T4
A
B
C
B'
C'
Magnetic Stimulation
0.5mV
5ms


Cz
Y
X
T4
Abductor Pollicis Brevis Muscle
Abductor Digiti Minimi Muscle
Bracioradial Muscles
Abductor Hallucis Muscle of the Foot
Abductor Digiti Minimi Muscle of the Foot





Change of membrane potential of 8 cm axon. Response to magnetic stimulation (Suprathreshold stimulus Icoil=600 A)

MRI – Magnetic fields used in MRI

- DC magnetic fields, B
  0.3 T – 4.0 T
- Rapid change in magnetic fields for gradient coils, dB/dt

  20 T/s ~ 80 T/s, 200 μs

  Sensation resulting from nerve stimulation
  20 T/s ~ 100 T/s, 200 μs
- Radio Frequency, SAR

  2 W/kg, 6 min. (whole body)
  10 W/kg, 6 min. (head)

601-2-33 © IEC:1995 – 69 –

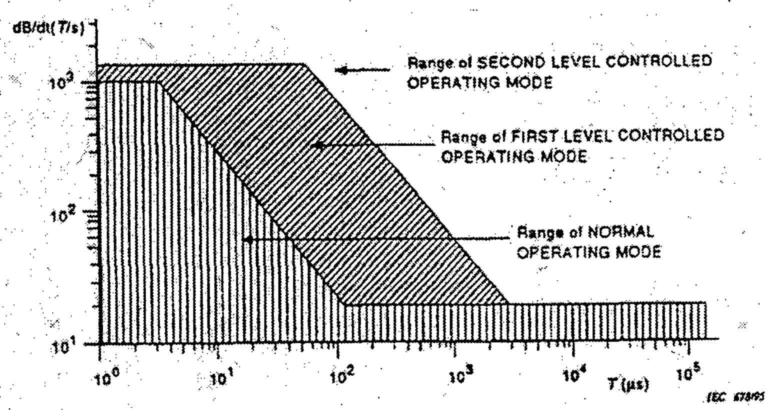
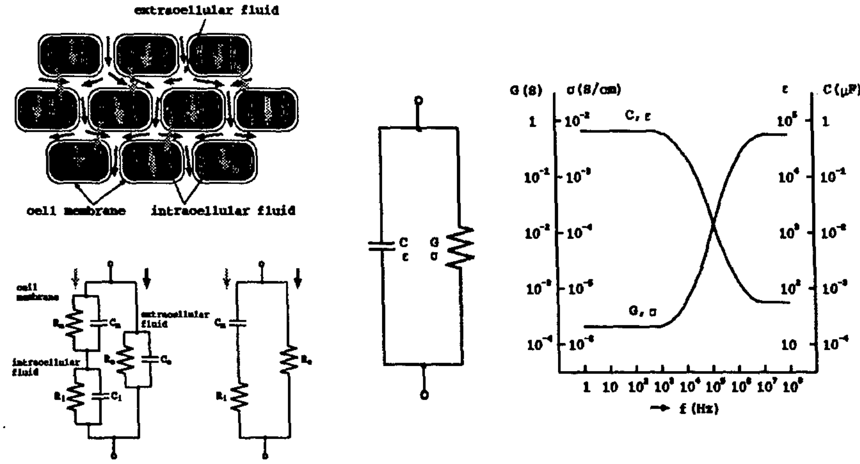


Figure 102 – Limits for dB/dt

Radio frequency electromagnetic fields

Frequency Characteristics of Electric Properties



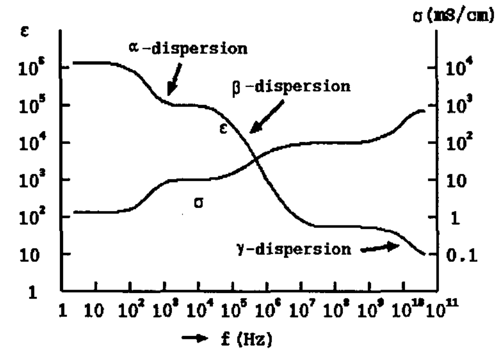
Dispersions of Electric Properties

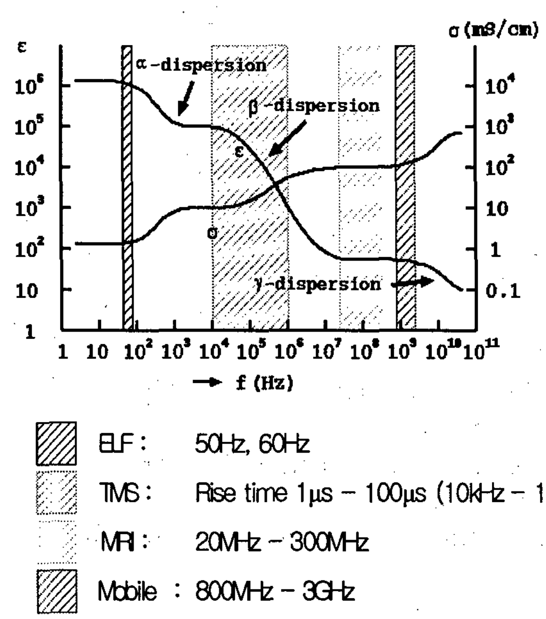
Complex permittivity
(dielectric constant and conductivity)

α-dispersion : Ionic atmosphere, Membrane surface conductance
f < 1kHz

β-dispersion : Structures of cells and tissues
~ 10kHz < f < ~ 10MHz

γ-dispersion : Dielectric dispersion of water molecules
f > 20GHz





SAR(Specific Absorption Rate) [W/kg]

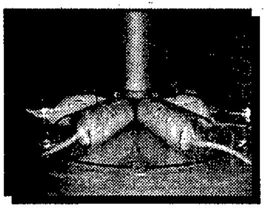
	Residential	Occupational
Local averaged SAR	2 W/kg	10 W/kg
Whole body averaged SAR	0.08 W/kg	0.4 W/kg

6 min averaged per 10 g of tissue

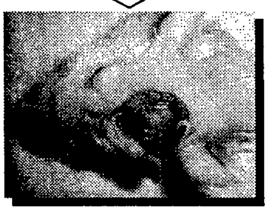
Research Program in Japan

1) neurological effects
2) mice skin cancer promotion
3) in vitro studies on genetic effects
4) in vivo study on the microcirculation of rat brain
5) two year national toxicology program (NTP) study of brain tumors of rats
6) epidemiological link between cellular phone use and tumor growth
7) effects on the permeability of the blood-brain-barrier (BBB) of rats
8) effects on learning and behavior
9) study of microwave hearing
10) in vivo study on eyes exposed to pulsed microwaves

Effect on the Brain



Microwave
Exposure to Brain



Brain Removal

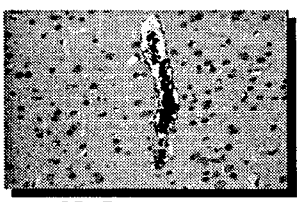
The Permeability of the Blood-brain Barrier

- Evans Blue
- Immunostained for Albumin

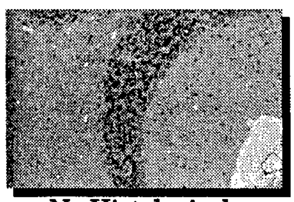
Histological Observation in Cerebellum

- Purkinje Cells
- Granular Layer

Effect on the Brain



No Increase in
BBB Permeability

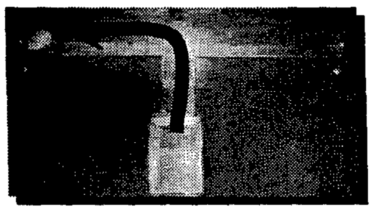


No Histological
Changes in Cerebellum

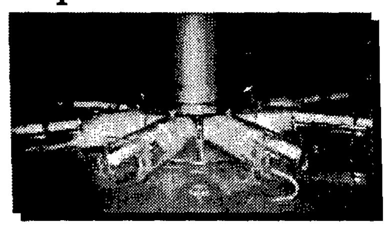
No Effects of Microwave on the Rat Brain at the Intensity of Mobile Phone

1439MHz TDMA field
Brain average SAR 0.99 W/kg
1 h/day, 4 week-exposure
Brain average SAR 7.5 W/kg
whole body average SAR 1.7 W/kg
4 h, one time
Brain average SAR 2 W/kg
whole body average SAR 0.25 W/kg
1 h/day, 4 week-exposure

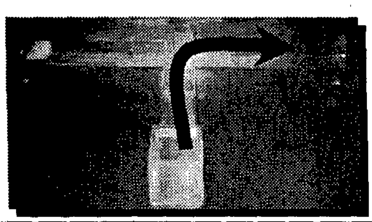
Effect on Learning & Memory



Microwave
exposure to Brain

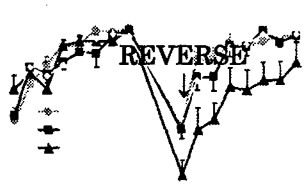


T-maze
Reversal Learning

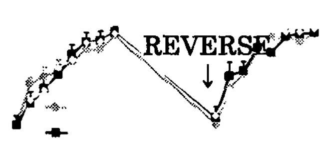


Rats learn and memorize
a new location of food
after the exposure

Effect on Learning & Memory



4-day Exposure



4-week Exposure

No Effects of Microwave
on Learning and Memory of Rats
at the Intensity of Mobile Phone

1439MHz TDMA field
Brain average SAR 7.5 W/kg
whole body average SAR 1.7 W/kg
1 h/day, 4 days or 4 week-exposure

WHO Meeting
on EMF Biological Effects and Standards Harmonization in Asia and Oceania

Review of Mobile Phone EMF Study

2001. 10. 22.

Chungnam National University

Jeong-Ki PACK

1

Chungnam National University

WHO Meeting
on EMF Biological Effects and Standards Harmonization in Asia and Oceania

CONTENTS

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I. INTRODUCTION

- Investigation of health effects of cellular phones requires carefully designed studies including accurate exposure assessment. Measurement standard for compliance test to existing regulations are also important, but not fully developed yet.
- In this paper, followings will be summarized
  - Key issues on EMF exposure in mobile phone frequency band
  - Relevant research activities in Korea, including guidelines, biological studies, epidemiological studies, dosimetry, SAR reduction techniques, measurement of EMF exposure environment.

II. KEY ISSUES of BIOLOGICAL STUDY

- **EMF Exposure Limit**
  - Exposure limits for mobile phone of most of the organizations and countries are based on well-understood thermal effect (← A temperature rise in human body due to exposure from strong EMF source).
- **Health Effect of Long-Term Low-Level Exposure**
  - There are a lot of controversie's on possible health effect of low-level exposure.
  - WHO's International EMF Project is focused on biological effects of long-term exposure in 900-2000 MHz frequency band used in mobile or cellular phone systems with exposure levels lower than exposure limits.

- **Exposure Guidelines for Mobile Phones**
  - Korea, IEEE/FCC in USA, and Canada: 1.6 W/kg, 1g averaged.
  - Europe and Japan: 2.0 W/kg, 10g averaged
- **Measurement Standard for Compliance test of Mobile Phones:** Under development in IEEE SCC34 and CENELEC, and to derive reproducible test procedure more researches are required.
- **KOREA**
  - KEES(Korea Electromagnetic Engineers Society) published recommendation on exposure limits based on ICNIRP guidelines in 1999.

- **MIC(Ministry of Information and Communication) announced three guidelines:**
  - ✓Guidelines for human protection from EMF exposure including local SAR limit for mobile phones,
  - ✓Guidelines for measurement of electromagnetic field,
  - ✓Guideline for measurement of SAR(will be effective from January 1, 2002).

WHO Meeting
on EMF Biological Effects and Standards Harmonization in Asia and Oceania

III. RESEARCH ACTIVITIES in KOREA

1996	Special study group on bioelectromagnetics
1997	Literature survey Dosimetry in mobile phone frequency ELF animal studies Assessment of EMF environment
2000	Biological researches on mobile phone EMF In vitro studies and epidemiological studies on-going
2002	Animal studies for local and whole-body exposure

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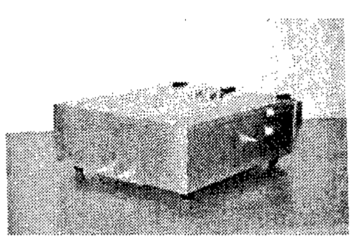
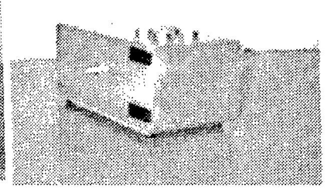
WHO Meeting
on EMF Biological Effects and Standards Harmonization in Asia and Oceania

Biological Studies:

In vitro studies in cellular and PCS frequency band

- ❑ **Exposure systems**





Cellular band	PCS band
32.8×10.0×42.0 cm	12.0×8.0×24.0 cm

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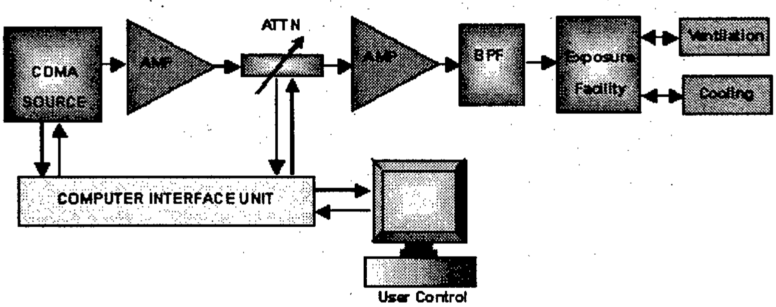
❑ System configuration



❑ In vitro experiment

- Subject: Two kinds of human cells(Jurkat human T lymphomia cell and WI-38 human fibroblast) and two kinds of mouse cells(DO11.10 mouse T cell hybridoma and C3H10T1/2 mouse fibroblast)
- Exposure level & Duration: 1.5 W/kg and 75 W/kg SAR for 30 min. and 12 hrs
- Results

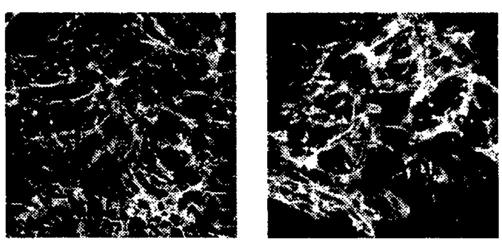


Fig. Actin Polymerization after 1.765 GHz RF Exposure in C3H10T1/2 Mouse Fibroblasts (a) Control and (b) exposed cells at 75 W/kg for 12 hours.

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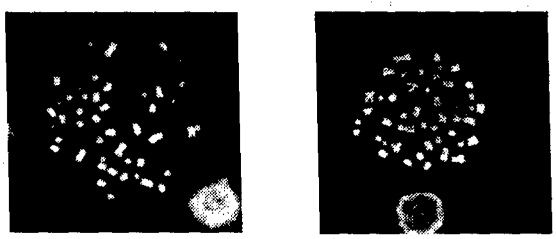

Fig. Karyotyping of Jurkat Human T Cell Lymphoma after 1.765 GHz RF Exposure (a) Control and (b) exposed Jurkat T cells at 75 W/kg for 12 hours.

- Conclusion: EMF does not cause any direct short-term effect on chromosome, but can cause stress response and reversible suppression of cell growth.

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Epidemiological Study

- **Scope:**
  - to perform an ecological correlation study using data bases on medical insurance, national death record, cancer registration record, and
  - to evaluate the association between cellular phone use and increase report of selected symptoms like headaches, dizziness, nausea, eye pain, fatigue, insomnia, concentration difficult difficulty, ear irritation, etc.
- **Subject:** more than 1,000 mobile phone users
- **Results:**
  - There is no statistical correlation in brain cancer and breast cancer, but a clear statistical correlation between thyroid cancer and mobile phone use was observed. →In order to confirm this result, further analytical epidemiological researches are required.

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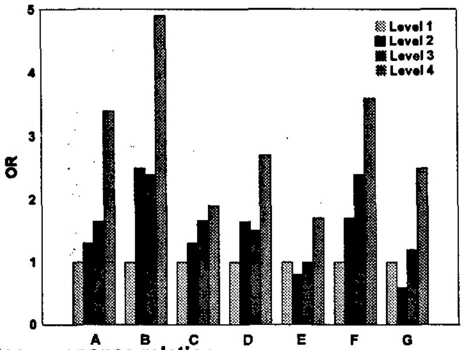
- Some correlation between symptoms and EMF exposure was found, but causal relation is not clear because this research is just a cross-sectional research. → To confirm this relation, additional analytical epidemiological study needs to be performed.



A: Dizziness
B: Nausea
C: Eye pain
D: Ear symptom
E: Fatigue
F: Heat sensation
G: Other symptoms

Fig. Dose-response relation between long-term cumulative exposure level and specific symptoms

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Dosimetry

- ❑ Scope:
  - to evaluate the amount of exposure due to mobile phones quantitatively, numerical and experimental methods
- ❑ Experimental method: Dielectric phantom, E-field probe, etc.
- ❑ Computational method: Numerical phantom, FDTD method, etc.
- ❑ Some Results:
  - Design and fabrication of SAR measurement probe
  - Measurement of SAR reduction components/substances
  - SAR analysis for various test positions
  - Development of numerical human head and body phantoms
  - Tissue-averaging method for assessment of local SAR
  - Changes in SAR due to head size
  - Uncertainty analysis

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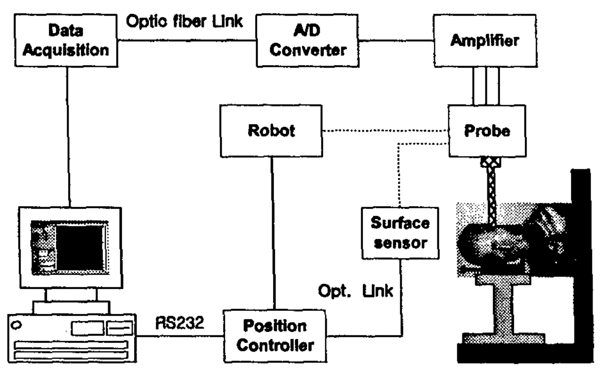

Fig. SAR measurement system setup developed in ETRI

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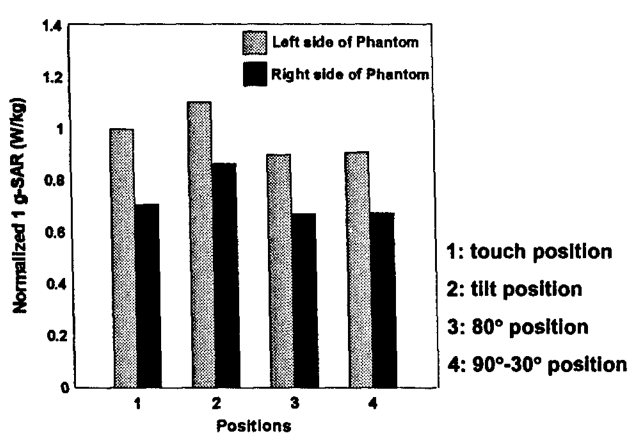

Fig. Localized SAR for different test positions

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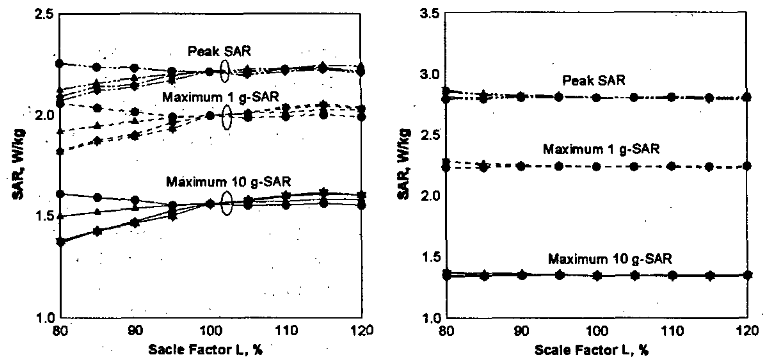

Fig. SAR results for scaled models.

●=Head breadth (mm)/158, (head length: 181 mm, chin-vertex length: 232 mm).
◆=Head length (mm)/181, (head breadth: 158 mm, chin-vertex length: 232 mm).
▲=Chin-vertex length (mm)/232, (head breadth: 158 mm, head length: 181 mm).
★=Head breadth (mm)/158=head length (mm)/181= chin-vertex length (mm)/232.

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SAR Reduction Technology

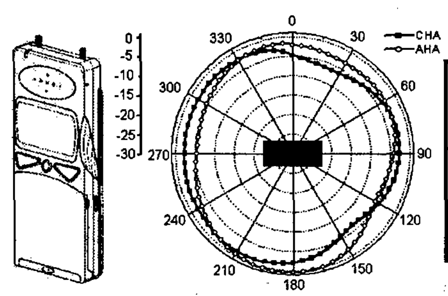

Fig. Phone with arrayed helical antennas & Comparison of radiation patterns

	Conventional Helical Antenna	Arrayed Helical Antennas
1g Avg.	1.04	0.673
10g Avg.	0.478	0.351

Table 1. Comparison of Measured SAR values (W/kg)

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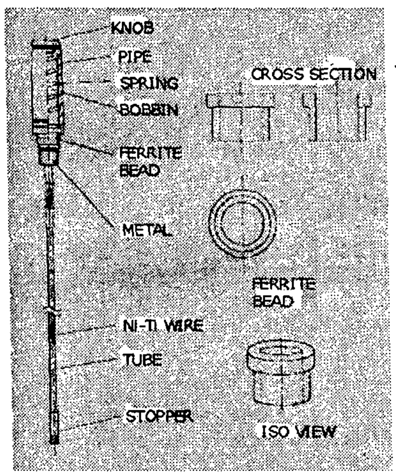

Fig. Mn-Zn cylindrical ferrite bead inside of the helical coil of the antenna.

- This mobile phone antenna was implemented with Mn-Zn cylindrical ferrite bead inside of the helical coil of the antenna.
- The maximum 1 g SARs with and without the ferrite bead insertion were measured at 824 MHz. The ferrite bead resulted in SAR reduction about 20 %, and reflection coefficient increase about 7 % for the extended antenna.

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Measurement of EMF Environment:
EMF levels around mobile phone base stations

- **No. of measured base stations: 24**
  - **6 stations for each service provider**
  - **equal number of base stations were selected for urban, suburban and rural environments**
- **Used Ant.: Isotropic 3-axis electric filed probe(HI-6005) and readout device of Holaday**
- **Frequency Range: 100 kHz ~ 5 GHz**
- **Electric field strength Range: 0.5 ~ 800 V/m.**

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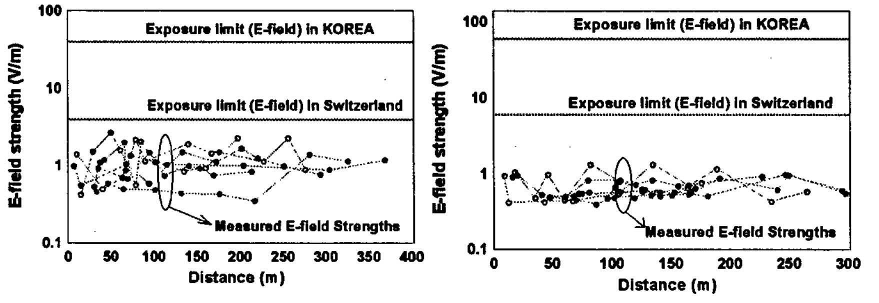

(a) Cellular base stations (b) PCS base stations
Fig. EMF levels around base stations

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on EMF Biological Effects and Standards Harmonization in Asia and Oceania

IV CONCLUSIONS

- ❑ Studies in this area were started in late 90's, but current research activities are quite active, especially in dosimetry and SAR reduction technology
- ❑ With the embarkment of the Korea EMF Project, EMF researches in mobile phone frequency become well organized
- ❑ International cooperations such as the International EMF Project are very important, and we join the variety of international activities currently going on worldwide.
- ❑ We expect a lot of progress will be made in various areas of mobile phone EMF research in Korea.

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CHARACTERISTICS, DOSIMETRY & MEASUREMENT OF EMF

Masao Taki

Not Available

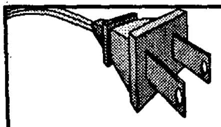
Review of health effects and gaps in knowledge

Dr MH Repacholi
Coordinator, Occupational and Environmental Health
World Health Organization, Geneva, Switzerland

WHO/ICNIRP/South Korean Government meeting
EMF biological effects and standards harmonization in Asia and Oceania
22-24 October 2001

Issues to be discussed

- ➔What are the known health effects of ELF and RF
- ➔Gaps in knowledge
- ➔How do we assess risks
- ➔Uncertainty in the science and public concern



Health effects of ELF field exposure are due to induced electric currents and fields.

Health effects: Nerve and muscle stimulation effects depend on the current density (> 10 mA/m^2)

Effects not established:

Cancer, memory loss, suicide, neurodegenerative such as Alzheimer's and Parkinson's disease, and subjective effects

ELF exposure

Known to induce electric fields and currents in the body

➔ICNIRP limits restrict induced currents from external fields to no more than endogenous currents

➔No adverse health effect established below these limits

Gaps in knowledge?

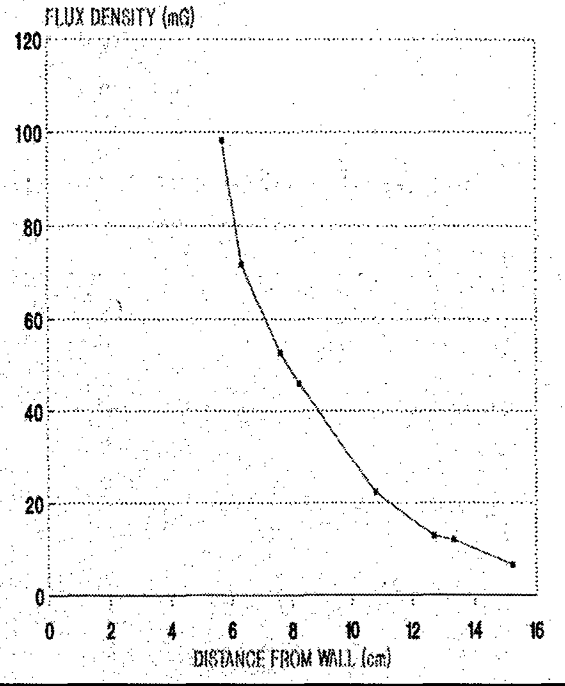
➔ELF magnetic fields classified as a "possible human carcinogen" by IARC: studies suggest association between exposure to these fields and childhood leukaemia

➔Are epi study results due to selection bias, contact currents, transients, other mechanisms etc?

➔No real support from animal or other studies

Transient magnetic flux density with distance from dimmer switch

(Ref: EPRI TR-103470, Residential transient magnetic field research, March 1994)



ELF fields and cancer

"Possibly carcinogenic to humans": IARC classification to denote agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals

This classification is the weakest of three categories ("is carcinogenic to humans", "probably carcinogenic to humans" and "possibly carcinogenic to humans") used by IARC to classify potential carcinogens based on published scientific evidence

Examples of agents classified by IARC

Classification	Examples of Agents
Carcinogenic to humans (usually based on strong evidence of carcinogenicity in humans)	Asbestos Mustard gas Tobacco (smoked and smokeless) Gamma radiation
Probably carcinogenic to humans (usually based on strong evidence of carcinogenicity in animals)	Diesel engine exhaust Sun lamps UV radiation Formaldehyde
Possibly carcinogenic to humans (usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)	Coffee Styrene Gasoline engine exhaust Welding fumes ELF magnetic fields

What should national authorities do about "Possible human carcinogens"

➢Other explanations possible for the observed association e.g. selection bias, exposure to other field types (transients, high frequency harmonics)

➢EMF Project helps national authorities balance benefits of electrical technology against possible health risks...help them decide what protective measures needed. Difficult to suggest protective measures because dont know what ELF field characteristic involved or if ELF magnetic fields responsible

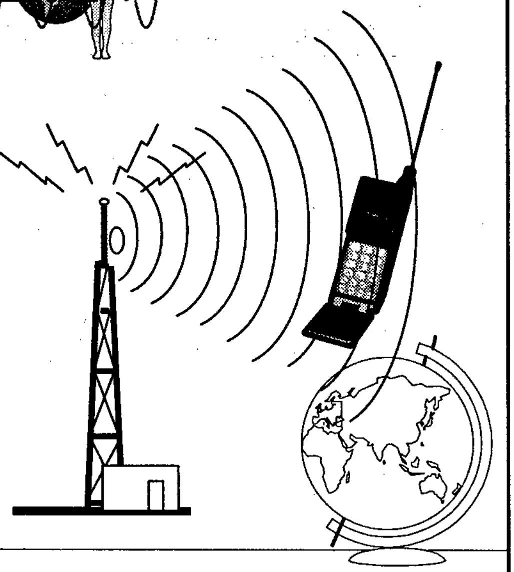
➢Need focused research program to elucidate possibilities

➢Suggest voluntary policies that aim to cost-effectively reduce exposure to ELF fields. See WHO Backgrounder (March 2000)

(see: http://www.who.int/peh-emf/publications/facts_press/EMF-Precaution.htm

RF health effects are due to heating from exposure above 4 W/kg

- Behavioural changes
- Reduced endurance
- Field avoidance



Effects not established:

- Memory loss
- Cancer
- Blood pressure changes
- Subjective effects
- Blood brain barrier

Health effects of RF fields

➢Known to cause heating that can affect animal behaviour, endurance etc...basis of ICNIRP and other standards

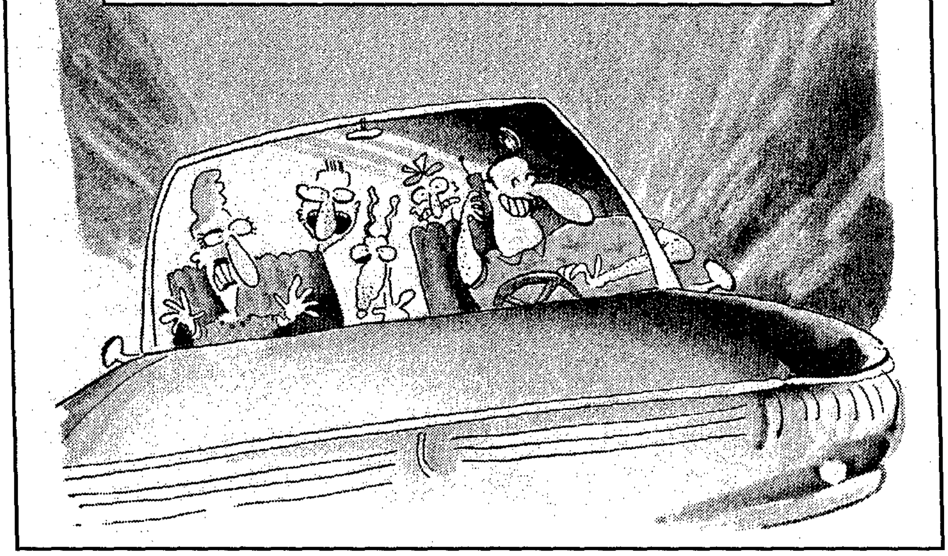
➢No other RF interaction mechanism established that could have health implications

➢"..balance of evidence to date suggests that exposure to RF radiation below NRPB and ICNIRP guidelines do not cause adverse health effects to the general population" IEGMP 2000

➢However there are effects reported on brain function etc, and hypothesise effects from pulsed signals that may or may not cause any health consequence that need further research.... IEGMP 2000

Health hazard of mobile phones:

Driving while using a mobile phone is dangerous



RF fields

Gaps in knowledge?

- **Some studies suggest effects below standards eg altered reaction times, effects on behaviour and sleep, hypersensitivity**
- **Some recent technologies lack studies eg mobile phones**
- **IEGMP recommended research as follows:**
  - **Effects on brain function**
  - **Consequences of exposure to pulsed signals**
  - **Improvements in dosimetry**
  - **..impacts of sub-cellular and cellular changes..**
  - **Psychological and sociological studies...**
  - **Epi and human volunteer studies, including study of children and individuals who might be more susceptible to RF...**

Electromagnetic Hypersensitivity (EHS)

- EHS has no clear diagnostic criteria
- There is no scientific basis to link EHS symptoms to EMF
- Similar range of non-specific symptoms as:
  - Multiple chemical sensitivities (MCS): attributed to low-level exposures to chemicals in the environment
  - Environmental somatization syndrome (ESS): attributed to environmental factors; sufferer rejects alternative explanations

Biological and Health Effects

- WHO defines health as a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity
- Biological effects are measurable responses to EMF exposure ....not necessarily hazardous
- Health hazard is a biological effect producing consequences outside the body's normal range of physiological compensation and is detrimental to health or well-being
- *Problem:* the public and media do not discern between biological and health effects

Psychosocial effects or hypersensitivity to EMF

- WHO's definition of health requires that effects such as headaches, sleep disturbance, irritability or other effects that compromise well-being must be taken into account
- Effects must be valid reproducible responses to EMF exposure

Electromagnetic Hypersensitivity (EHS)
EHS Symptoms

- Nervous system symptoms (e.g. sleep disturbances, fatigue, stress)
- Skin symptoms (e.g. facial prickling, burning sensations, rashes)
- Various body symptoms (e.g. pain and ache in muscles)
- Eye symptoms (e.g. burning sensations)
- Various less common symptoms that include ear, nose, and throat problems, as well as digestive disorders
- Symptoms faced by EHS individuals are certainly real

Electromagnetic Hypersensitivity (EHS)

Assisting EHS individuals

- **Medical evaluation to identify and treat conditions responsible for symptoms**
- **Hygienist evaluate workplace or home for factors that might contribute to the symptoms**
- **Physicians communicate and help develop strategies for coping**
- **Provide EHS individuals, health-care professionals and employers with targeted and balanced information about EMF and a statement that no scientific basis exists for a connection between EHS and exposure to EMF**

EMF fields

What is the way forward?

- **Need a thorough review of all scientific studies**
- **Properly coordinated and focused research program to fill gaps required for better health risk assessments**
- **Clear research agenda for scientists to complete**
- **When "sufficient" research completed need recognised health risk assessment program to evaluate results and risks to health**
- **Health risk assessment program should be oriented to advise national authorities on protecting their populations**
- **Process and information must be disseminated in a user-friendly way to the public, workers, government and industry**

Hill Criteria to Assess Health Risk

- Strong association between exposure and risk?
- Consistent association between exposure and health outcome?
- Dose-response relationship?
- Good laboratory evidence to support epi results?
- Plausible biological mechanism(s)?

Not all criteria need to be met...and seldom are...

but data as a whole need to be convincing!

Hill, A.B. The environment and disease: Association or causation? Proceedings of the Royal Society of Medicine 58 295-300 (1965)

Overall assessment: Weight of evidence

- All evidence considered as a whole: No one study is definitive
- Scientific judgement: reflecting strength of evidence from studies in humans, animals and other relevant data
- No way to prove something does not cause effects; need to determine how much a set of evidence changes probability that exposure causes an outcome
- Health risk assessments by WHO Task Group

Uncertainty in the science and public concern

Public concern about possible health hazards

- Some epidemiological studies suggest a weak association between exposure to EMF and a variety of health problems (eg ELF magnetic fields classified by IARC as "possible human carcinogen"....how will they classify RF fields?)
- Some unreplicated reports of biological effects at EMF levels below international guidelines have been published
- Some technologies (e.g. mobile phones) are relatively new, and few health studies have been performed using EMF characteristics they emit
- Established exposure guideline limits may not protect certain sub-populations who may be more sensitive to EMF (e.g. children, hypersensitives)
- Large national variations in EMF exposure limits, and therefore different levels of protection....creates great uncertainty in the public mind

Role of the *Precautionary Principle* in EMF to be discussed by Dr Kheifets

Further information

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Occupational and Environmental Health
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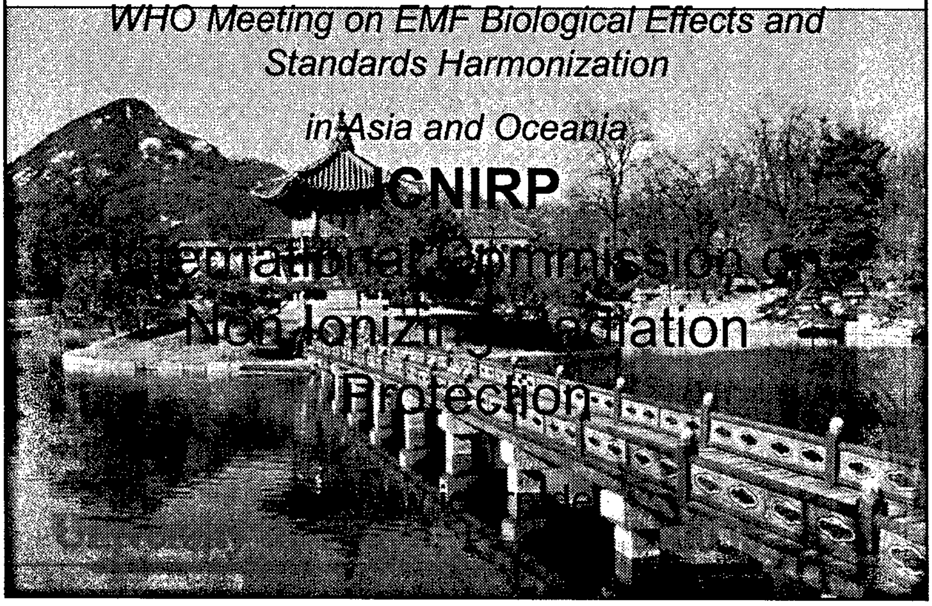
E-mail: kheifetsl@who.int
Home page: www.who.int/emf/

Seoul



WHO Meeting on EMF Biological Effects and Standards Harmonization

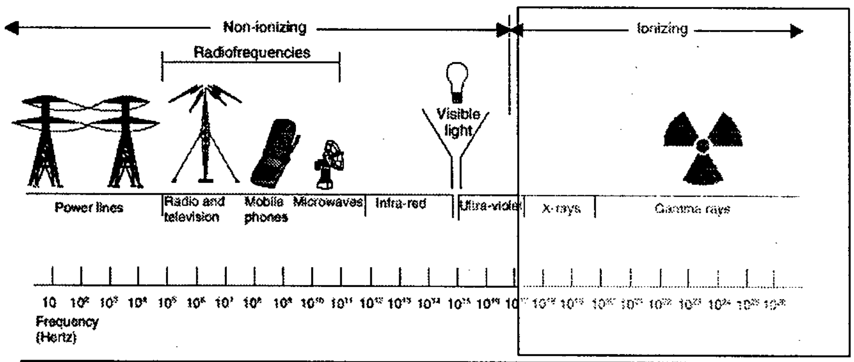
in Asia and Oceania

ICNIRP

International Commission on Non-Ionizing Radiation Protection

ICNIRP Spectrum

Fields - Radiation - Effects - Disciplines



Epidemiology

Medicine and Biology

Physics and Engineering

History of ICNIRP

- "The Beginnings": IRPA and INIRC

1973 - IRPA 3rd Congress: Session on NIR
1974 - IRPA establishes NIR working group
1977 - IRPA includes NIR: INIRC formed
INIRC - 12 members and Chairman
- Works with WHO and UNEP to produce EHCs

History of ICNIRP

"Cutting the Cord" - The Charter

1992 - Montreal IRPA-8 Congress - INIRC becomes ICNIRP
- No industry members - tenure limited.
- ICNIRP registered in Germany as a non-profit making body
- M. Repacholi is elected as first chairman

"ICNIRP Proper"

- 1992-1996

Exposure Guidelines

Static magnetic fields   Ultraviolet radiation

- 1996-2000   *Chairman J. Bernhardt*

Exposure Guidelines

EMFs to 300 GHz - Laser radiation - Broad-band optical

Ultraviolet radiation - Compilation of guidelines

Restructuring

Standing Committees etc.

ICNIRP 2000-2004

ICNIRP Main Commission

- Standing Committee I Epidemiology
- Standing Committee II Biology
- Standing Committee III Physics & Engineering
- Standing Committee IV Optical Radiation

Commission Membership 2000-2004

Dr. A.F. McKinlay	Chairman, UK
Prof. J.H. Bernhardt	Vice Chairman, Germany
Prof. Dr. A. Ahlbom	Sweden
Dr. U. Bergqvist	Sweden
Dr. J.P. Césarini	France
Dr. F. R. De Gruijl	The Netherlands
Dr. M. Hietanen	Finland
Dr. R. Owen	USA
Dr. D.H. Sliney	USA
Prof. A. Swerdlow	UK
Prof. Dr. M. Taki	Japan
Dr. T.S. Tenforde	USA
Dr. P. Vecchia	Italy
Dr. B. Veyret	France
Dr. M.H. Repacholi	Chairman Emeritus CH
Ing.R.Matthes	Scientific Secretary, Germany

Standing Committees

- Reviewing the scientific literature specific to the field of interest of each Standing Committee.
- Preparing specific reports and other publications requested by the Main Commission.
- Advising on the preparation of exposure guidelines and other ICNIRP documents requiring multi-disciplinary input.
- Providing expert advice through ICNIRP-organised scientific seminars and other scientific meetings.

Standing Committee I

Epidemiology

Chairman: Anders Ahlbom, Sweden

Anthony Swerdlow, UK

Elisabeth Cardis, France

David Savitz, USA

Adele Green, Australia

Martha Linet, USA

Standing Committee II

Biology

Chairman: Bernard Veyret, France

Russ Owen, USA

Tom Tenforde, USA

Frank de Gruij, NL

Richard Saunders, UK

René de Seze, France

Gregory Lotz, USA

Luc Verschaeve, Belgium

Standing Committee III

Physics and Engineering

Chairman: M. Taki, Japan

P. Vecchia, Italy

Stuart Allen, UK

Kari Jokela, Finland

Colin Roy, Australia

Howard Bassen, USA

Standing Committee IV

Optical Radiation

Chairman: David Sliney, USA

Jean-Pierre Césarini, France

Bruce Stuck, USA

Brian Diffey, UK

Martin Mainster, USA

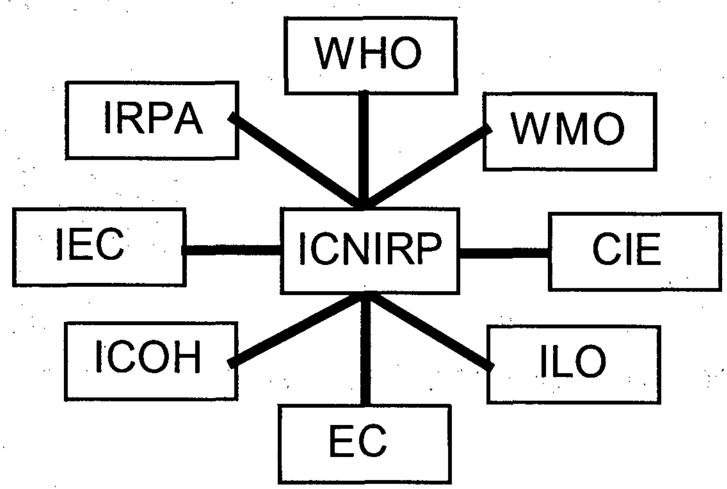
Tsutoma Okuno, Japan

Consulting Members

ICNIRP's Needs

- To have additional and often technology-specific expertise
- To widen scientific input to ICNIRP's activities and broaden consultation
- First wave, 20 so far appointed across all Standing Committees

Partners in NIR Protection



ICNIRP and WHO

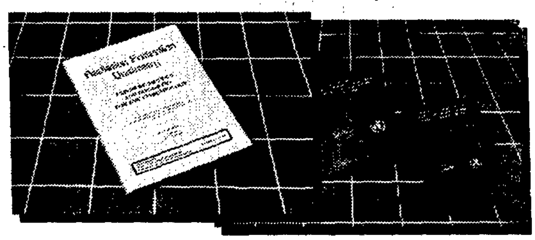
The International EMF Project

The INTERSUN Programme

Scientific Reviews

Jointly Organised Conferences and Workshops

Joint Publications

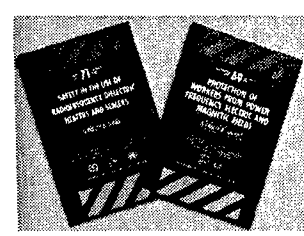


ICNIRP and ILO

International Labour Organisation

Occupational Exposure Guides

- VDUs
- Lasers
- ELF electric and magnetic fields
- RF heater sealers



Protection of Workers from UVR

ICNIRP and the EC

European Community

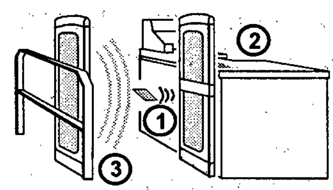
Electronic Article Surveillance,
RF Identification Devices and Metal Detectors

EC 5th Framework Concerted Action

Advisory report to EC covering

Epidemiology

Biology



Measurements and compliance assessments

Possible interference with medical implant devices

Report scheduled for February 2002

Present and Future Challenges Scientific Reviews

ELF Epidemiology (SC I) - in press in "Environmental Health Perspectives"

ELF Biology (SC II) - complete by March 2002

ELF Physics (SC III) - complete by December 2001

RF Epidemiology (SC I) - start early 2002

RF Biology (SCII) - start early 2002

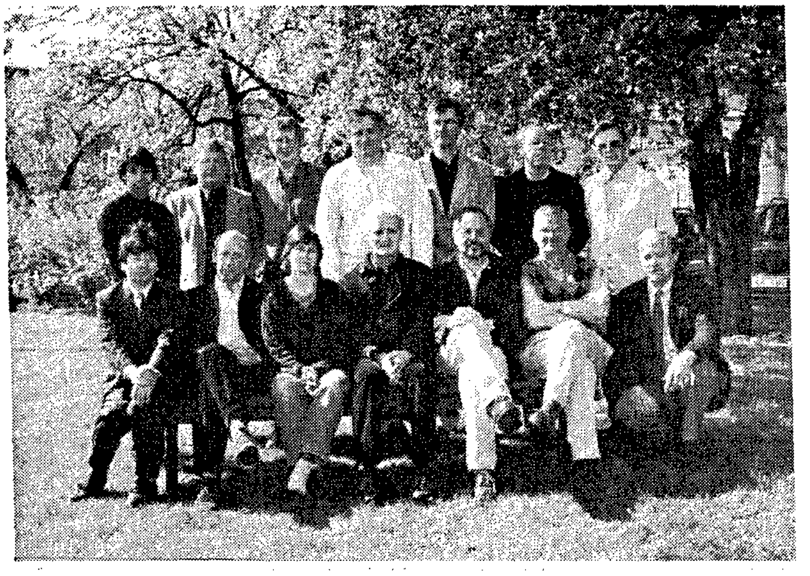
RF Physics (SC III - start early 2002

All to contribute to WHO's Health Risk Assessments

Present and Future Challenges Other Tasks

- General System of Protection against NIR
- Statement on "Pulsed Magnetic Fields"
- Completing a workers guide on UVR exposure for ILO
- Completing an EC 5th Framework Report on EAS, RFID and metal detector devices
- Statement on UVR Sunbeds and considering the need for one on medical ultrasound
- Need to update its advice on limiting exposure to UVR, to airborne ultrasound
- MRI (Workshop Organised in October 2001)

Present and Future Challenges: Communication & Consultation



IEEE

EMF Health & Safety Standards

IEEE
Networking the World™

Seoul, Korea
23 October 2001

Patrick Mason, PhD
Radio Frequency Radiation Branch
Human Effectiveness Directorate
Air Force Research Laboratory

Institute of Electrical and Electronics Engineers (IEEE)

The IEEE is one of the largest professional societies in the world (325,000 members, 1/3 from outside of the U.S) and is composed of a number of professional societies (e.g., Engineering in Medicine and Biology Society) that sponsor standards committees

Standards pertaining to subjects that are of interest to more than one society (e.g., RF safety standards) are developed by *Standards Coordinating Committees (e.g., SCC-28, SCC-34),* that are sponsored by the IEEE Standards Board

History of ANSI/IEEE
RF/Microwave Exposure Standards

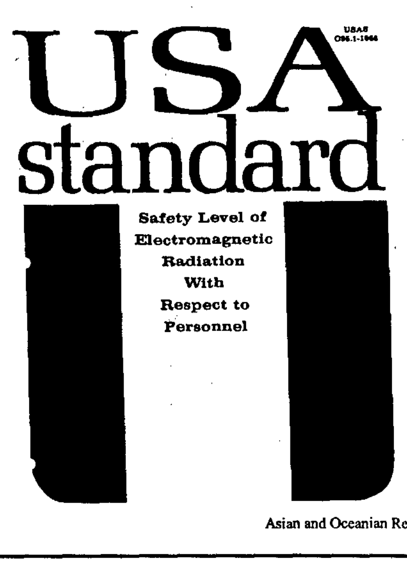
1953 **10 mW/cm² recommended to US Navy**
- **based on simple thermal model**

1959 **USASI C95 Committee/Project chartered**
- **sponsored by U.S. Navy and IEEE**

1966 **American National Standards Institute (ANSI) C95.1-1966 approved**
- **based on simple thermal models**

Asian and Oceanian Regional EMF Scientific Meeting, 2001

C95.1 - 1966 (later ANSI/IEEE C95.1)



Sponsors

U.S. Department of the Navy
Institute of Electrical and Electronics Engineers

Approved November 9, 1966
United States of America Standards Institute

10 MHz - 100GHz

10 mW/cm²

0.1-hour (6 minute) averaging time introduced

1.2 pages long

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History of ANSI/IEEE RF/Microwave Exposure Standards

1971 ANSI C95.1-1971 approved

- **10 mW/cm^2 - based on simple thermal models**
- **limits for E^2 and H^2**

1982 ANSI C95.1-1982 approved

- **incorporates dosimetry**
- **frequency dependent**
- **based on threshold specific absorption rate (SAR) for behavioral disruption**

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Why is Specific Absorption Rate (SAR) important?

- **The incident and internal electromagnetic fields can be very different, depending upon size and shape**
- **SAR is the common unit for comparing and extrapolating laboratory results (bioeffects studies)**

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History of ANSI/IEEE RF/Microwave Exposure Standards

1986 National Council on Radiation Protection and Measurements (NCRP) publishes recommendations:

- **SAR - based**
- **occupational exposure limits the same as ANSI C95.1-1982**
- **lower limits for the general public**

1988 ASC (ANSI) C95 Committee becomes IEEE SCC-28

Asian and Oceanian Regional EMF Scientific Meeting, 2001

History of ANSI/IEEE RF/Microwave Exposure Standards

1991 C95.1-1991 approved by IEEE Standards Board

- **SAR - based**
- **two tier**
- **induced current limits**
- **relaxation for partial-body exposures**
- **contains rules and definitions necessary for implementation**
- **based, in part, on literature evaluation**

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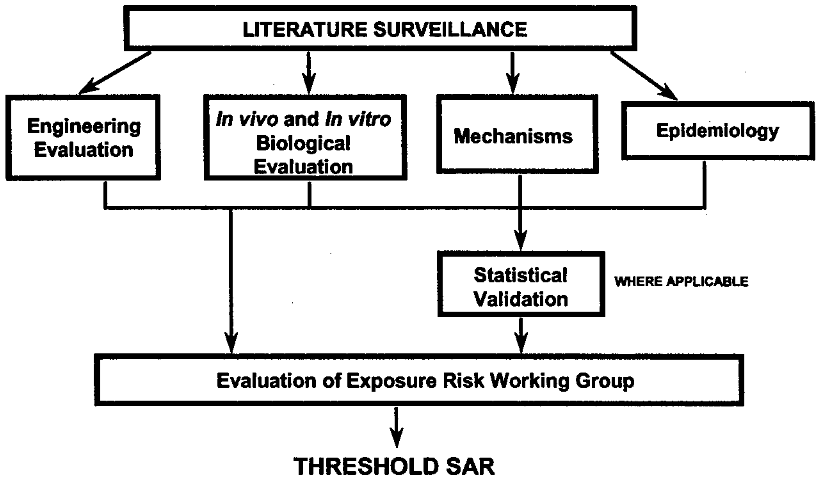
IEEE SCC-28 - Subcommittee 4
Literature Evaluation Process



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Goals of Literature Assessment

During the literature assessment procedure, classifications of findings were made *without* prejudgement of mechanisms of effects

Intent was to protect exposed human beings from harm by *any* mechanism, including those arising from excessive elevations of body temperature

Asian and Oceanian Regional EMF Scientific Meeting, 2001

Biological Validation Working Groups

Behavior	Genetics
Biorhythms	Modulation
Cardiovasculature	Hematology-Immunology
Endocrinology	Metabolism-Thermoregulation
Oncology	Central Nervous System
Combined Effects	Development and Teratology
Physiology	Visual Systems

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IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz,
IEEE C95.1-1991

FINDINGS:

The most sensitive measures of potentially harmful biological effects were based on the disruption of food-motivated behavior in several animal species under widely-varying field parameters

Asian and Oceanian Regional EMF Scientific Meeting, 2001

Comparison of Power Density and SAR Thresholds of Behavioral Disruption

Species and Conditions	CW 225 MHz	Pulsed 1.3 GHz	CW 2.45 GHz	Pulsed 5.8 GHz
Norwegian Rat				
Power Density:	—	10 mW/cm^2	28 mW/cm^2	20 mW/cm^2
SAR:	—	2.5 W/kg	5.0 W/kg	4.9 W/kg
Squirrel Monkey				
Power Density:	—	—	45 mW/cm^2	40 mW/cm^2
SAR:	—	—	4.5 W/kg	7.2 W/kg
Rhesus Monkey				
Power Density:	8 mW/cm^2	57 mW/cm^2	67 mW/cm^2	140 mW/cm^2
SAR:	3.2 W/kg	4.5 W/kg	4.7 W/kg	8.4 W/kg

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IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE C95.1-1991

The MPEs are based on limiting the SAR to:

	Controlled/ Occupational	Uncontrolled/ General Public
Whole-Body-Averaged	0.4 W/kg	0.08 W/kg
Spatial Peak (per gram)*	8.0 W/kg	1.6 W/kg

*Per gram of tissue in the shape of a cube

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IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz,
IEEE C95.1-1991

Controlled Environments

Controlled environments are locations where there is exposure which may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons or as the incidental result of transient passage through areas where analysis shows that the exposure levels may be above the maximum permissible exposure (MPEs) for the uncontrolled environment but do not exceed the MPEs for the controlled environment.

IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz,
IEEE C95.1-1991

Uncontrolled Environments

Uncontrolled environments are locations where there is exposure of individuals who have no knowledge or control of their exposure. The exposures may occur in living quarters or workplaces where there are no expectations that the exposure levels exceed the MPEs for the uncontrolled environment.

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IEEE C95.1-1991 - Spatial Averaging

The exposure values (the values that are compared with the appropriate MPEs) in terms of electric and magnetic field strengths are the mean values obtained by spatially averaging the squares of the fields over an area equivalent to the vertical cross-section of the human body (projected area)

Note: The spatial average can be obtained by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human. An approximate method for spatial averaging is to make measurements at equal intervals (at least ten) along the axis of the projected area of the exposed subject. The spatial average is equal to the sum of the squares of the measured fields divided by the number of measurements

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IEEE C95.1-1991: AVERAGING TIME (HIGH FREQUENCIES)

The averaging time decreases with increasing frequency (above 15 GHz) from 6 and 30 minutes for the controlled and uncontrolled environments, respectively, to 10 seconds at 300 GHz

Note: The 10 second averaging time at 300 GHz (1 mm wavelength) is consistent with ANSI Z136.1-1993 (for the safe use of lasers) at 1 mm (where the two standards meet). The averaging time was reduced in the 1991 standard to preclude 2nd degree skin burns associated with short exposures at frequencies where the energy is absorbed in superficial tissues. For example, a 6 minute averaging time and a 5 mW/cm^2 MPE allows exposure to a peak power density of 3.6 W/cm^2 for a 0.5 sec exposure (once every 6 minutes) which is above the threshold for skin burn from a white light or infrared source.

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IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz,
IEEE C95.1-1991

Summary of Standard

"Recommendations are made to prevent harmful effects in human beings exposed to electromagnetic fields in the frequency range of 3 kHz to 300 GHz"

These exposure limits are biologically based and reflect a consensus interpretation of relevant studies from the bioelectromagnetics literature by qualified scientists, physicians, and engineers. Adjustments to the recommendations as a convenience to special interest groups are not a part of the process

Asian and Oceanian Regional EMF Scientific Meeting, 2001

IEEE Standards Coordinating Committee 28
1997

Literature evaluation started for next revision

- **~ 1300 citations in database**
- **non-peer reviewed papers, e.g., book chapters and reports, are included**
- **evaluations by topic**

Some issues that will be addressed are:

- **microwave/millimeter wave averaging time**
- **the need for two tiers**
- **spatial-peak SAR values and averaging volume**

Asian and Oceanian Regional EMF Scientific Meeting, 2001

Revision of IEEE C95.1-1991: Literature Evaluation

The ~1300 citations currently in the literature database are organized as:

- **engineering**
- **epidemiology**
- ***in vitro***
- ***in vivo***
- **peripheral**

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RF/Microwave Standards Activities

IEEE Standards Coordinating Committee 28 is one of the several international organizations that develop safety criteria for RF/microwave exposure

For standards harmonization, it is important that members of these international organizations interact with one another to understand rationale for exposure limits

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Importance of IEEE/ICES SCC-28 Activities (C95 Standards)

- forty year history of ANSI C95 standards
- broadest scientific consensus
- forms basis for numerous modern standards
- U.S. federal agencies mandated to adopt voluntary standards
- FDA models product performance standards after ANSI standards, e.g., microwave ovens
- developed through open consensus

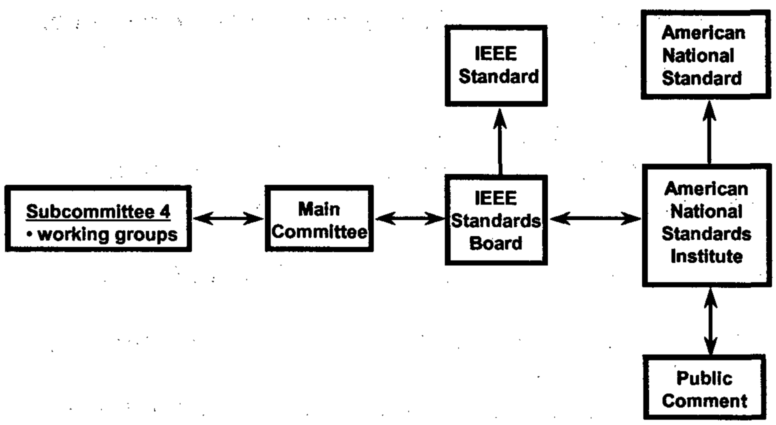
Institute of Electrical and Electronics Engineers (IEEE) SCC-28 Procedures

Approval of an IEEE Standard Requires:*

- balance of interests on committees
- 75% return of ballots (including abstentions)
- approval of 75% of returned ballots (excluding abstentions)
- attempts made to reconcile all negative ballots
- circulation of unreconciled ballots to allow voters to reaffirm, comment or change their vote
- coordination with other societies and organizations

*Required at the subcommittee level *and* at the main committee level

IEEE SCC-28 Standard-Setting Process



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IEEE/ICES SCC28 Executive Committee

Chair: Dr. Eleanor Adair

Past Chair: Dr. John Osepchuk

Executive Secreatary: Ronald Petersen

Treasurer: Arthur Varanelli

Membership: Dr. Tom McManus

International Liaison: Dr. Michael Murphy

Asian and Oceanian Regional EMF Scientific Meeting, 2001

IEEE/ICES SCC-28

Over 100 Members from 13 countries

SCC28 Main (Parent) Committee

- **Policy, procedures, broad direction, and administration**
- **Adherence to Process**

5 subcommittees (SC)

- **SC1: Techniques, Procedures, & Instrumentation**
- **SC2: Terminology, Units of Measurement, and Hazard Communication**
- **SC3: Safety Levels with Respect to Human Exposure, 0-3 kHz**
- **SC4: Safety Levels with Respect to Human Exposure, 3 kHz – 300 GHz**
- **SC5: Safety Levels with Respect to Electro-Explosive Devices**

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<u>Membership Affiliations for SCC-28/SC-4</u>
(SC-4: 3 kHz – 300 GHz)

Research:university	**37**	**(30%)**
nonprofit		**8**
(6%)		
military	**15**	**(12%)**
non-military government	**30**	**(24%)**
Industry	**12**	**(10%)**
Industry - Consulting	**4**	**(3%)**
Government - Administration	**5**	**(4%)**
General Public & Independent Consultants	**14**	**(11%)**

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Membership Principle Disciplines for SCC-28/SC-4

Physical Sciences	41	(33%)
Life Sciences	54	(43%)
Medicine	12	(10%)
Radiology, Pharmacology, Toxicology	4	(3%)
Others (Law, Medical History, Safety, etc.)	14	(11%)

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History of ANSI/IEEE RF/Microwave Exposure Standards

2001 **IEEE SCC-28 becomes IEEE/ICES SCC-28**

(International Committee on Electromagnetic Safety)

Asian and Oceanian Regional EMF Scientific Meeting, 2001

Invitation to Participate

IEEE Networking the World
Safety Standards
for
Electromagnetic
(EM)
Energy

Standards
Coordinating
Committee 28
(SCC28)

INTERNATIONAL
COMMITTEE on
ELECTROMAGNETIC
SAFETY
IEEE

- **IEEE/ICES is an International Consensus Standard Setting Body**
- **We welcome your participation**
- **To learn more about IEEE/ICES:**
  - **(http://grouper.IEEE.org/groups/scc28)**
  - **e-mail Tom McManus (tommcmanus@dpe.ie)**

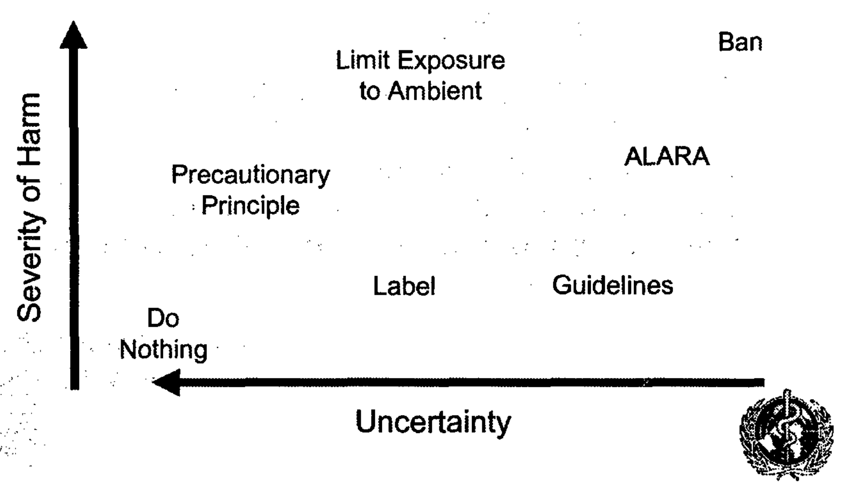
Asian and Oceanian Regional EMF Scientific Meeting, 2001

The Precautionary Principle & EMF

Dr Leeka Kheifets
Head, Radiation Program
Occupational and Environmental Health
World Health Organization, Geneva, Switzerland

WHO Meeting on EMF Biological Effects and Standards
Harmonization in Asia and Oceania
Seoul, South Korea
22-24 October 2001

Range of Actions



Precaution

- Growing movement to adopt *precautionary approaches* to manage health risks with scientific uncertainty
- WHO does not normally advise national authorities to set policies that go beyond established knowledge
- At Ministerial Conference on Environment and Health in London 1999, WHO encouraged to take into account "the need to rigorously apply the Precautionary Principle in assessing risks and to adopt a more preventive, pro-active approach to hazards."

Definition

The Precautionary Principle (PP)

> "Take prudent action when there is sufficient scientific evidence (but not necessarily absolute proof) that inaction could lead to harm and where action can be justified on reasonable judgments of cost-effectiveness."

Treaty of Maastricht
quoted by WHO 1999

Precautionary Principle
European Commission (2000)

"...the precautionary principle is neither a politicisation of science [nor] the acceptance of zero-risk but that it provides a basis for action when science is unable to give a clear answer... the precautionary principle is not a justification for ignoring scientific evidence and taking protectionist decisions."

Differences that Make the Difference

- Strength of evidence
  - Possible cause
  - No conclusive scientific proof
  - Sufficient evidence
- Requirement to act
  - Consider action
  - Take cost-effective action
  - Prevent or eliminate exposure
- Burden of proof
  - Opponents
  - Proponents

Application of PP to EMF

- Prudent Avoidance
  - Prudent avoidance means taking simple, easily achievable, low cost measures to minimize exposure, even in the absence of a demonstrable risk.
  - "An example of using incomplete science to make a reasoned judgment in the face of uncertainty" — G. Morgan

Application of PP to EMF

- Prudent avoidance adopted in Australia, Sweden, and several U.S. states (California, Colorado, Hawaii, New York, Ohio, Texas, Wisconsin)
  - Low-cost steps (less than 4% of project budget) in constructing new lines in California
  - Best available practices

Application of PP to EMF

"If measures generally reducing exposure can be taken at reasonable expense and with reasonable consequences in all other respects, an effort should be made to reduce fields radically deviating from what could be deemed normal in the environment concerned. Where new electrical installations and buildings are concerned, efforts should be made to design and position them in such a way that exposure is limited."

National Authorities
Sweden, 1996

Scientific Uncertainty and Application of PP to EMF

- Small risk to all vs. large risk to few
- Unknown aspect of exposure that might be harmful
  - Some actions might increase risk
- Clear benefit of electricity to health

Specifics of Application of PP to EMF

- Benchmark using existing exposure levels
- Distinguish new and existing facilities
- Distinguish voluntary and involuntary sources of exposure
- Distinguish exposure to children and adults

Criticisms of PP as it Applies to EMF

- Too far
  - Abandonment of science
  - Setting precedent
  - Slippery slope
- Not enough
  - Too utilitarian
  - Environmental justice
- Not well defined

PP: Define, Refine or Replace?

- Risks are always present and there are always some uncertainties
  - Possibility of risk in itself does not justify action
  - Uncertainty in itself does not justify inaction
- One must consider tradeoffs
  - Other risks
  - Risk to others
  - Benefits
  - Costs

PP: Define, Refine or Replace?

PP General principle in need of framework

- Who is practicing PP
  - Individual
  - Industry
  - Society
- What is the setting
  - Health
  - Occupational
  - Environment
- Who pays and who benefits

PP: Define, Refine or Replace?

PP General principle in need of framework

- Should not undermine scientific evaluations and science-based guidelines
- Unified terminology with risk evaluations
- Means to reduce uncertainty
- Ways to monitor and refine consequences of action
- Admit that evaluation of risk is based
  - on science
  - and judgment

National Radiation Laboratory

EMF exposure Standards in New Zealand

Martin Gledhill
National Radiation Laboratory
Ministry of Health
New Zealand

National Radiation Laboratory

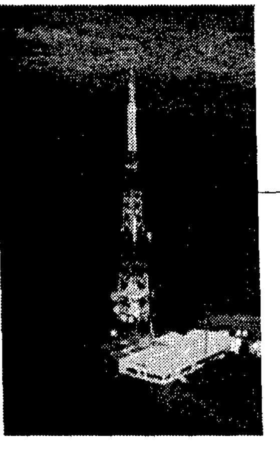
Overview

- Development of RF exposure Standard
- Features of the Standard
- Government initiatives
- Recommendations at other frequencies
- Australian Standard

National Radiation Laboratory

Development of the RF Standard

- Initiated by developments at a major transmission site
- Existing Australian Standard adopted
- Amalgamated with Australian committee for further development



National Radiation Laboratory

Standards process

- Standards NZ sets up committee representing interest groups
- Draft released for public comment
- Committee vote on final draft
- Attempt to resolve negative votes
- Minimum of 80% of votes must be in favour

National Radiation Laboratory

NZS 2772.1:1999

- Adopted as New Zealand Standard in 1999
- Covers frequency range 3 kHz – 300 GHz
- Basic Restrictions and Reference Levels taken from ICNIRP 1998
- Additional clauses to aid implementation and verification of compliance

National Radiation Laboratory

Verification of compliance

- Clauses on how to demonstrate compliance an important requirement for users
- Clauses include
  - Spatial averaging
  - Near/far field measurements
  - Mobile/portable transmitters

National Radiation Laboratory

Implementation - occupational

- Policy on protection/responsibility
- Reduce exposures through engineering/administrative controls
- Identify areas of high exposures

National Radiation Laboratory

Implementation - public

- Requirements to:
  - minimise exposures provided that this can be achieved at modest expense
  - Operate in accordance with best industry practice

National Radiation Laboratory

Legal status of Standard

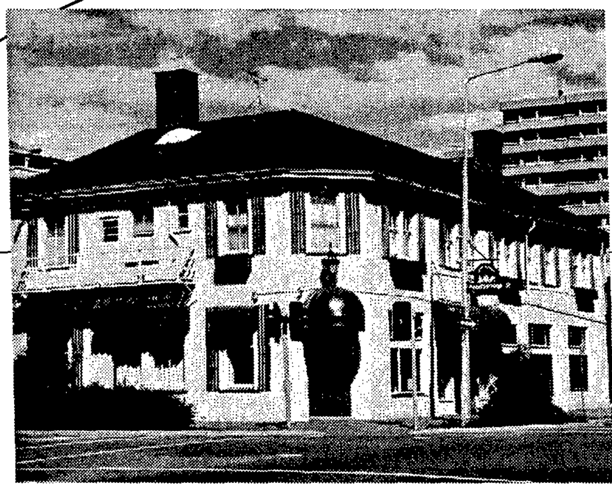
- Standard has no direct legal status
- Supported by Ministries of Health and for the Environment
- Supported in planning case law
- Incorporated in planning rules by some local authorities
- Would probably be cited as an appropriate occupational safety Standard

National Radiation Laboratory

Public acceptance

- Public perception that Standards committee loaded in favour of industry
- Leadership from government agencies valuable for local authorities
- Commitment to continuing review of research important

National Radiation Laboratory



National Radiation Laboratory

National Radiation Laboratory

Other frequencies

- Ministry of Health recommends ICNIRP guidelines at other frequencies
- ICNIRP guidance at power frequencies incorporated in some local planning rules

National Radiation Laboratory

Developments in Australia

- NZS 2772.1:1999 not adopted in Australia
- Objections included:
  - Averaging time
  - Increase in reference levels above 400MHz
- ARPANSA given responsibility to develop a new Standard

National Radiation Laboratory

Australia: current status

- ARPANSA draft based largely on ICNIRP, plus a precautionary statement
- Public comments reviewed, Standard should be published in late 2001
- ACIF developing Code of Practice for installation/operation of RF infrastructure

National Radiation Laboratory

Conclusions

- Availability of credible and comprehensive international guidance important for small countries
- Standard must have wide support to be effective

ELECTROMAGNETIC FIELD (EMF) EXPOSURE STANDARD IN CHINA

Huai Chiang

Not Available

EMF Standards in Japan

Masao Taki
Tokyo Metropolitan University

Guidelines in Japan

- ELF (50/60Hz)
  - **Electric field strength < 3 kV/m at the edge of "Right-of-Way" (1976)**
  - **Regulation under the Ministerial Ordinance of Standards for Electrical Equipments (Agency of National Resources and Energy, ANRE)**
  - **Not for health protection but regulation of facility installation**
  - **No guidelines on magnetic fields (ICNIRP guidelines provide *de facto* guidance**
- RF (10 kHz – 300 GHz)
  - **Radio-Radiation Protection Guidelines for human exposure to EMF (1990, 1997)**

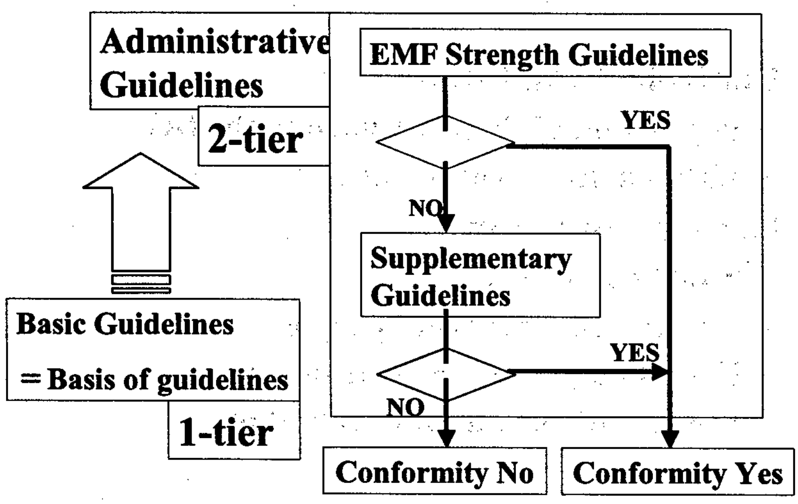
Radio-Radiation Protection Guidelines for human exposure to EMF (RRPG)

- In 1988 Inquiry to the "Telecommunications Technology Council" by the Minister of Posts and Telecommunications
  - Guidelines for human exposure to EMF
  - Measurement procedures
- 1990 Report by TT Council
  - Radio-Radiation Protection Guidelines for human exposure to EMF (RRPG)
- 1997 Additional Report by TT Council
  - Amendment of "exemption of low power devices < 7W" in 1990 guideline
    - Partial absorption guideline

Nature of RRPG

- Initiative by the National Government authority (Ministry of posts and Telecommunications, MPT) on telecommunications
- Consensus standard
  - TT Council consisted of experts from all disciplines (engineering, medicine, occupational health) as well as those involved in vested interest.
- Started as voluntary guideline in 1990
- Legislation in 1999 (base stations, etc) and in 2001 (hand-held devices) by MPHPT
  (MPT was reorganized in 2001 and become MPHPT)

Structure and Application Procedure of RRPG



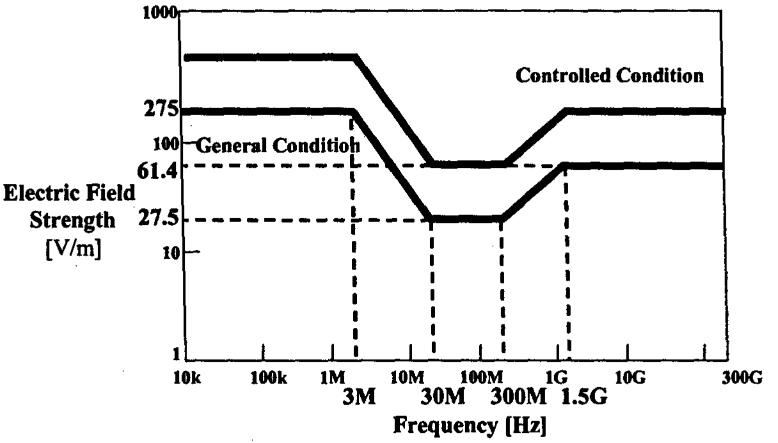
1-tier BG and 2-tier AG

- Basic guideline (1-tier)
  - Average healthy people is assumed
  - Provide the basis for guidelines to be used in practical situations.
- Administrative guideline (2-tiers)
  - To be used for administration of EMF environment and exposure
  - Variation of population members and uncertainty are considered

2-tiers

- **Controlled condition**
  - **Population of those assumed in the BG**
  - **EMF environment is controlled**
- **General condition**
  - **"Not" controlled**
  - **May include "weaker" people**
  - **Uncertainty of EMF environment**
  - **Uncertainty of exposure condition**

Electromagnetic Field (EMF) Strength Guideline
(Average time: 6 minutes)



Supplementary Guidelines (1)

- Inhomogeneous or local exposure (source distance >10 cm)

f [Hz]	10 k□300 M	300 M□1 G	1 G□3 G	3 G□300 G
Spatial Ave. of EMF-S G	< EMF Strength Guideline			
Spatially max. of EMF [mW/cm^2] CC / GC		trunk : 20/4		Surface : 50 /10
			head : 10/2	eye : 10/2
Space applied	Space occupied by body, where > 20 cm from the source	Space occupied by body, where > 10 cm from the source Note:Not applicable to mobile phones		
Ave. time	6 min.			

Supplementary Guidelines (2)

- **Contact current**
  - **10 kHz□100 kHz (ave. time <1 sec)**
    - **<10^{-3} f /Hz (Controlled Condition)**
    - **<4.5×10^{-4} f/Hz (General Condition)**
  - **100 kHz□15 MHz(ave. time 6min.)**
    - **<100mA (Controlled Condition)**
    - **< 45mA (General Condition)**

Supplementary Guidelines (3)

- Induced limb current
  - 3 MHz□300 MHz
    - <100mA (Controlled Condition)
    - < 45mA (General Condition)

Partial-Body Absorption Guideline (PAG)

- Applicable to small sources used in the vicinity of the body

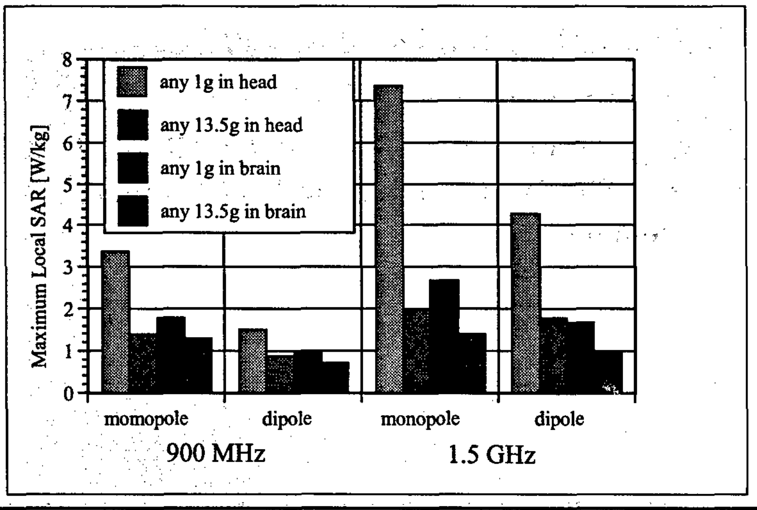
	Controlled Cond.	General Cond.
Frequency	100 kHz□3 GHz	
Averaging time	6 minutes	
Whole-body ave. SAR	0.4 W/kg	0.08 W/kg
Max. SAR in any 10 g tissue	10 W/kg 20 W/kg (limb)	2 W/kg 4 W/kg (limb)

Compromise of PAG with BG

- Basic guidelines
  - 8 W/kg for 1g tissue except surface part of body and limbs
  - 24 W /kg for 1 g tissue in surface part and limbs.
- Partial-body absorption guideline
  - Controlled condition
    - 10 W/kg for any 10 g tissue except limbs
    - 20 W/kg for any 10 g tissue in limbs
  - General condition
    - 2 W/kg for any 10 g tissue except limbs
    - 4 W/kg for any 10 g tissue in limbs

Comparison of SARs in Head using MTE

(M.Taki, S.Watanabe, T.Nojima, 1996)



Summary (1)

- RF guideline in Japan was first set in 1990
  - Basically it followed IEEE/ANSI figures
  - 1-tier basic guideline and 2-tier administrative guide
  - Basic guideline is not used directly in compliance assessments but provides the basis for administrative guideline
  - Administrative guideline include "reference levels" as well as "basic restrictions"
  - Used as a voluntary guidance

Summary (2)

- RF guideline modified in 1997
  - Modified to rather ICNIRP's figures
  - Legislation of guidelines under "Radio Law" in 1999 (fixed stations) and 2001 (mobile phones)

END

EMF SAFETY STANDARDS IN MALAYSIA

Ahmed Farag

Not Available

ETRI

Electronics and Telecommunications Research Institute

EMF Standards and Researches in Korea

YOO Dong-Sik, PhD

EMF Environment Team
Radio & Broadcasting Research Lab

ETRI

Contents

1. Public Concerns I

- Public concerns associated with power lines, mobile phones and base stations are increasing continuously each year, which is fueled mainly by mass media.
- Number of Petitions in 2000
  - Power lines : 120
  - Base stations : 152
- A number of persons appeal that they are suffering from EMF hypersensitivity.
- Some of them argued that symptoms were too severe to be able to live normally

3 ETRI Proprietary

1. Public Concerns II

- Survey of Public Opinions on Health Effects of EMF
  - Survey Organization : Educational Broadcasting System(EBS) (Live poll on 7 Oct 1999)
  - Opinions on Health Effects:
    Adverse (88.8%), Not Adverse (11%), Others (0.2%)
  - Establishment of Act for Regulating EMF:
    For (76.6%), Against (22%), Others (1.4%)
  - Regulating Method:
    Mandatory (51.2%), Recommendation (48.4%), Others (0.4%)
  - Support of Government for EMF Research:
    Necessary (75%), Not Necessary (24%), Others (1.0%)

4 ETRI Proprietary

ETRI

2. EMF Policies I

■ **Adoption of National Guidelines**

◈ **In December 1999, the article 47-2 of the "Radio Wave Act" was revised and then proclaimed in January 2000.**

◈ **In December 2000, MIC announced officially four separate ordinances :**

- **Exposure limits for EMF and SAR**
- **Measurement method for EMF**
- **Measurement method for SAR**
- **Installations and devices to which the exposure limits apply**

◈ **They will be enforced from 1 January 2002.**

◈ **Precautionary policies are not adopted**

5 ETRI Proprietary

ETRI

2. EMF Policies II

■ **Adoption of National Guidelines (continued)**

◈ **Will be in effective from 1 January 2002.**

◈ **The ordinances are not mandatory regulations, but recommendatory.**

■ **New Mobile-Phone Policies**

◈ **SAR values for each mobile phone available on the market will be measured and then the results will be published by the end of this year.**

◈ **A mandatory rule to restrict the use of mobile phones in moving vehicles has been adopted.**

◈ **Hands-free devices should be applied while driving from 1 July 2001.**

6 ETRI Proprietary

ETRI

2. EMF Policies III

■ **Generation of a New National EMF Research Project**

- ◆ **In 2000, a five-year EMF research project funded mainly by the government has been started .**
- ◆ **The total amount of the budget will be reached about $8.5m for the duration of the project .**
- ◆ **Main research topics are as follows: dosimetry, in vivo and in vitro studies for middle frequency (MF) and radio frequency (RF) exposures, epidemiological studies.**
- ◆ **Several other research projects such as health effects for the extremely low frequency (ELF) exposures have been investigated.**

7 ETRI Proprietary

ETRI

3. EMF Standards I

■ **Exposure Limits for EMF Intensities**

- ◆ **Regulate maximum permissible level of electric field, magnetic field, or power density, generated by stationary installations, appliances, etc.**
- ◆ **Frequency range: 0 – 300 GHz**
- ◆ **Two-tier standard: General public/Workers**
- ◆ **Exceptions:**
  - **Mobile radio stations**
  - **Installations operated in an emergency or a natural disaster**
  - **Facilities installed in the area such as mountains where the general public do not enter frequently**
  - **Low-power devices**

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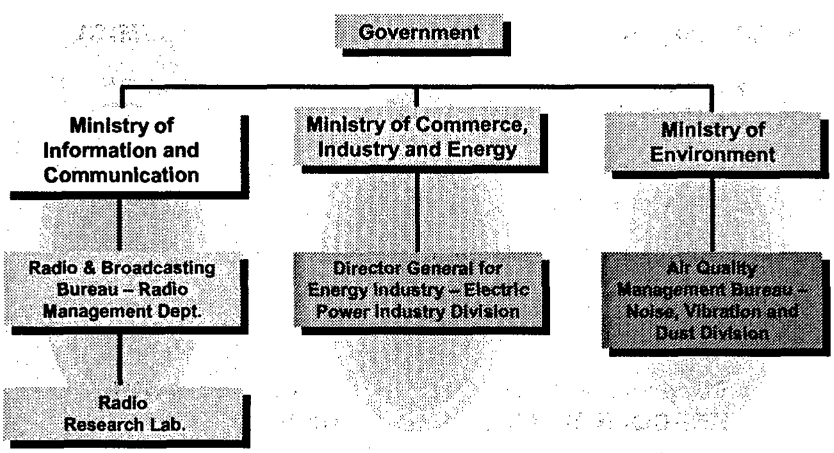
ETRI

3. EMF Standards II

- ▣ **Exposure Limits for EMF Intensities (continued)**
  - ◈ **Closely follows the ICNIRP guideline**
  - ◈ **Limits for induced current, contact current, and pulsed EMF are not included.**
- ▣ **Exposure Limit for SAR**
  - ◈ **Regulates maximum permissible level of spatial peak SAR in local exposure environments.**
  - ◈ **Frequency range: 100 kHz – 10 GHz**
  - ◈ **One-tier standard: General public only**
  - ◈ **Applies only to mobile telephones**
  - ◈ **Based on the IEEE/ANSI guideline**

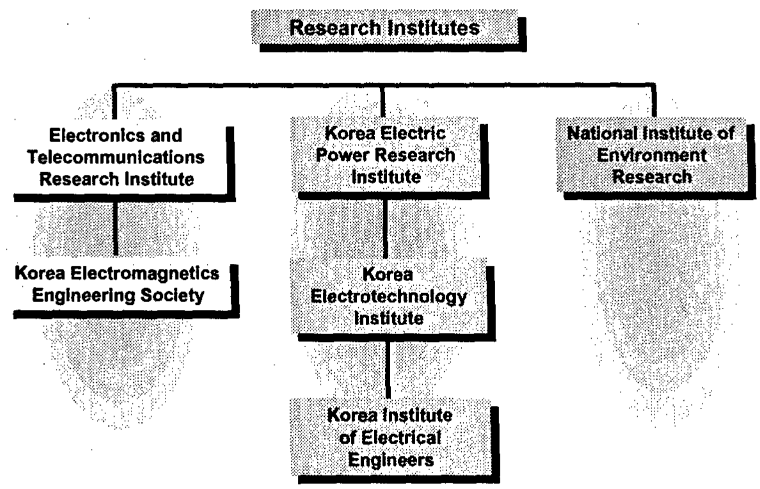
ETRI

4. Related Organizations I



ETRI

4. Related Organizations II



ETRI

4. Related Organizations III

- Ministry of Information and Communication (MIC)
  - ◈ Supports EMF researches (mainly MF and RF), collaborating with ETRI, KEES, RRL.
  - ◈ Prepares and publishes regulations for protection from EMF exposure
  - ◈ Supports International EMF Project
- Ministry of Commerce, Industry & Energy, and Ministry of Environment
  - ◈ Supports ELF researches, collaborating with KEPCO, KEI, KIEE, KRICT, NIER.

ETRI

5. EMF Researches – Dosimetry I

- ◈ The SAR measurement procedure has been studied in order to determine the peak SAR value in the human head for mobile phones experimentally.
- ◈ An E-field probe for the compliance test of mobile phones has been designed and fabricated.
- ◈ SAR reduction techniques for mobile phones have also been investigated extensively.
- ◈ Effects of the head size on the electromagnetic absorption and a mass-averaging technique for localized SAR such as 1g-SAR or 10g-SAR have been investigated.

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ETRI

5. EMF Researches – Dosimetry II

- ◈ A numerical phantom using a volunteer with the domestic head shape was also developed.
- ◈ A whole body model is under constructed.
- ◈ The dielectric properties for pathological tissues cultivated by the xenograft method have been analyzed to model the frequency dispersion behavior of them.

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6. In vivo & In vitro Study I

◈ Electric fields at 60 Hz were applied to expose mice up to three generations.

◈ For the exposure levels of the ICNIRP guideline, there was no significant health effect.

◈ However, for the high level exposure, it was found that congenital abnormalities were possible and the immune system and reproduction function would be affected adversely.

◈ Rats have been exposed to saw tooth magnetic fields of 20 kHz in order to elucidate the effects of the MF exposures on subacute toxicity, malformation upon gestational age and carcinogenic effects combined with environmental carcinogens.

6. In vivo & In vitro Study II

◈ Human fibroblast cells and T-lymphocyte cells have been exposed to fields of 848.5 MHz and 1.8 GHz which have been used in mobile telecommunications.

◈ Cell proliferation and destruction, cell transformations, chromatic aberrations, alterations in gene expression and stress responses have been investigated.

◈ It is planned that mice will be exposed to the frequencies of 848.5 MHz and 1.8 GHz in order to investigate the possible causes of adverse health effects.

ETRI

7. Epidemiological Study I

◈ Epidemiological studies of carcinomas (leukemia, malignant lymphoma, brain tumor, breast cancer) for the residents near AM radio stations were performed.

◈ The purpose was to investigate an association between residing near radio broadcast towers and carcinogenic appearance based on a geographical correlation design.

◈ Among ten exposed areas, two areas were showed significantly high incidence for leukemia and brain tumor compared to control areas.

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7. Epidemiological Study II

◈ For malignant lymphoma and breast cancer, however, there were no significantly increased areas.

◈ Results suggested the necessity of further analytical epidemiological studies with more precise exposure measurement and information of confounding factors.

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ETRI

7. Epidemiological Study III

◈ For the RF exposures from mobile phones, a cross-sectional symptom survey was carried out.

◈ The preliminary result showed that there would be a correlation between the number of phone uses and thyroid carcinoma.

◈ However, there was no correlation for brain tumor and breast cancer.

◈ Symptoms such as dizziness, nausea, heat perception in cheek, fatigue in eyeball and pain in ears were reported.

19 ETRI Proprietary

ETRI

7. Epidemiological Study IV

◈ Positive dose-response relations were observed.

◈ Further analytical study with more information of confounding factors will be investigated in the following year.

20 ETRI Proprietary

ETRI

8. Conclusions

- ◈ EMF standards and policies in Korea were introduced.
- ◈ EMF researches including SAR measurements, in vivo and in vitro studies for the EMF exposures and epidemiological studies were also discussed.
- ◈ It is expected that scientific results from the EMF researches in Korea would contribute to the WHO EMF project.

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CELL HYDRATION AS AN ESSENTIAL CELL PARAMETER FOR ESTIMATING THE BIOLOGICAL EFFECT OF ELECTROMAGNETIC FIELD

Sineric Ayrapetyan

Not Available

ROLE OF MODULATION IN DEVELOPMENT OF EMF SOMATIC EFFECTS

Yu. Grigoriev *

Not Available

AN EPIDEMIOLOGICAL STUDY ON ELF-EMF AND CHILDHOOD CANCERS IN JAPAN (1999-2001)

Michinori Kabuto *

Not Available

Summary of Basic Reseach Subjects on Bioelectromagnetics Issued in China

Zhojin Cao *

Not Available

DEALING WITH RADIOFREQUENCY RADIATION: THE EXPERIENCE IN THE REPUBLIC OF THE PHILIPPINES

Agnette P. Peralta and Elizabeth H. Mendoza *

Not Available

EFFECTS OF WHOLE BODY EXPOSURE TO 50Hz ELECTROMAGNETIC FIELDS ON THE LEUKOCYTEADHESION IN MICE

A. Ushiyama and C. Ohkubo *

Not Available

NATIONAL PROGRAM FOR TRAINING IN RISK PERCEPTION, RISK COMMUNICATION AND RISK MANEGEMENT AS A POLICY OF PRECAUTIONARY APPROACH

M. Israel, V. Zaryabova

Not Available

Institut für Normale und
Pathologische Physiologie
Zentrum für Elektropathologie

universität Witten/Herdecke

Titel

Different Aspects of Electromagnetic Hypersensitivity

A. Wojtysiak, J. Reißenweber, F. Gholamrezaei, E. David
Institute of Physiology and Physiopathology
Electropathological Research Center of the
University Witten/Herdecke

☎ 02302/669-347 ⌧ 02302/669-316 ✉ wojty@uni-wh.de www.uni-wh.de

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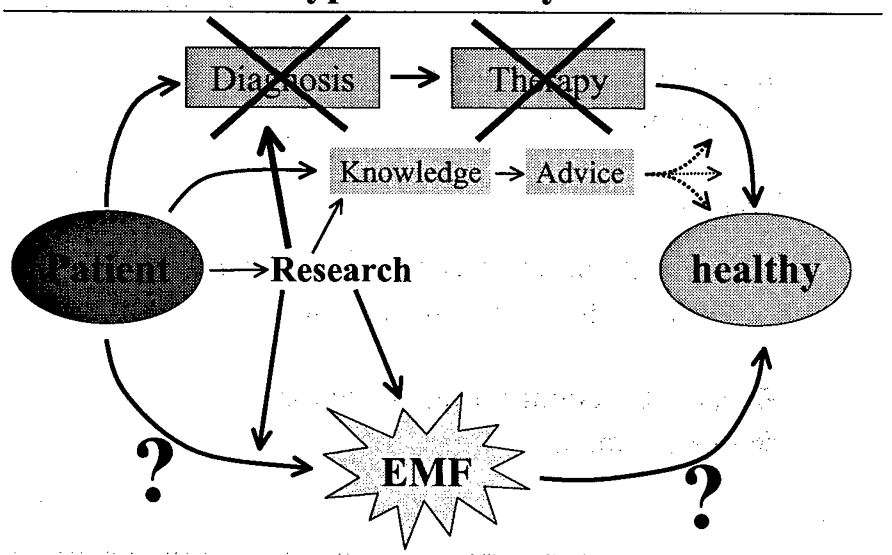
Electromagnetic Hypersensitivity



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Research

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- Questionnaires:
  - »specially designed
  - »Hypochondry-Hystery-Inventory HHI
- Medical Check:
  - »Anamnesis
  - »General and Neurological Examination
- Exposure Experiments

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Hypochondria-Hystery-Inventory

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Standardized Psychological Evaluation
11 Patients tested

Results:

- no hypochondric or hysteroid tendencies
- criteria not to be used for diagnosis

➔ cannot account for phenomenon
➔ evaluation ceased

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Procedure

- Introductory Conversation
- Medical Anamnesis
- 1. Test series
- Psycho-social Anamnesis
- Medical Examination
- 2. Test series
- Blood Sampling
- Final Discussion and Advice

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Symptoms

symptoms \ patients	16	17	18	21	22	23	24	25	26	29	30	31	32	33	34	abundance
exhaustion	■	■	■	■	■	■	■	■	■		■	■	■	■		13
sleep disorders	■	■	■		■	■	■			■	■	■	■	■	■	12
concentration failure	■	■	■		■	■	■	■	■	■		■	■	■		12
back pains	■	■	■				■	■		■	■	■	■	■		10
headache	■	■		■						■	■	■	■	■	■	9
allergies			■		■	■	■		■	■				■	■	8
feeling of oppression				■	■	■		■	■	■			■	■	■	9
crawling sensation		■			■	■	■	■	■					■	■	8
depression			■	■	■	■			■							5
cardiac pains		■					■			■			■		■	5
hypertension		■											■		■	3
IEI	■	■					■									3
PMLs (pg/ml)	5,8	16	8,1	8,8	15,9	9,1	8,4	14,0	79	10	9,7	14	9,2	8,6	7,7	
average score	70%	50	50%	65%	50%	50%	35%	60%	55%	50%	55%	65%	50%	40%	70%	54,5

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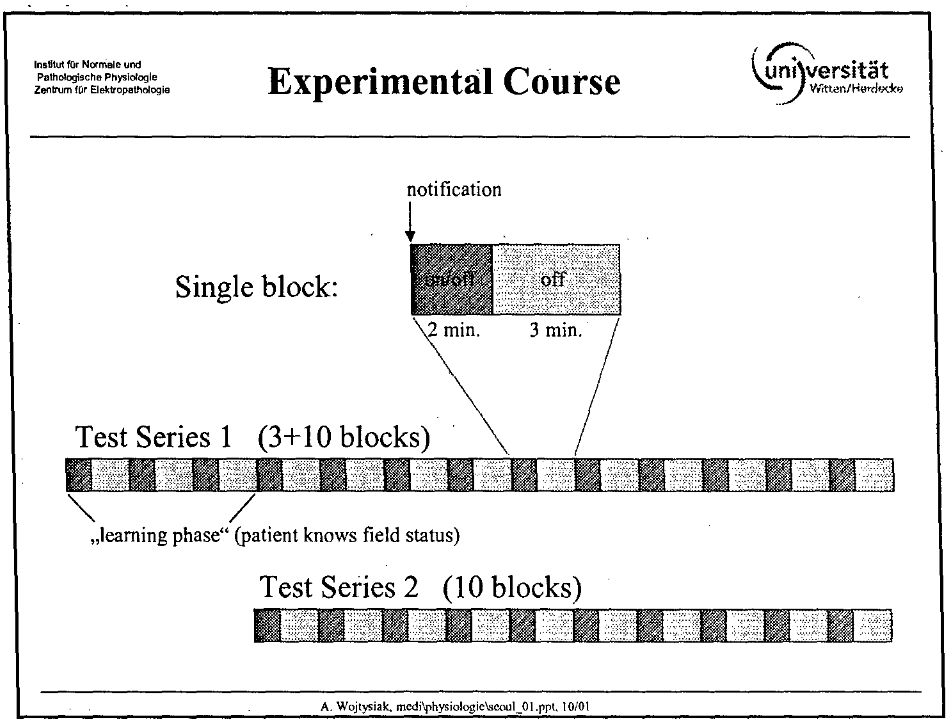
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Experimental Course
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notification
Single block:
on/off
off
2 min.
3 min.
Test Series 1 (3+10 blocks)
„learning phase“ (patient knows field status)
Test Series 2 (10 blocks)
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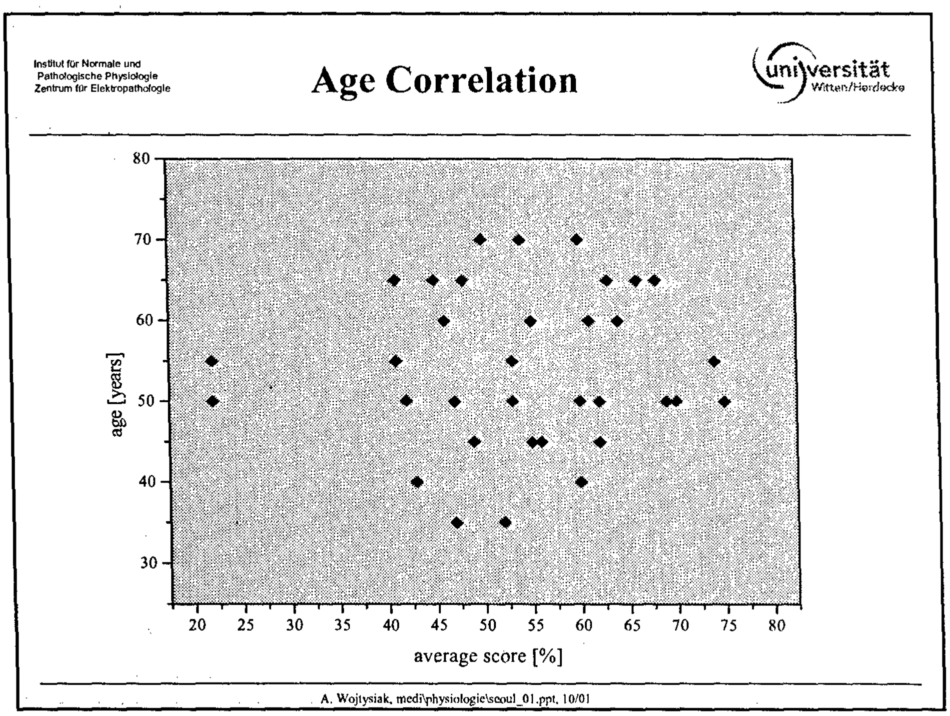
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Age Correlation
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80
70
60
50
40
30
age [years]
20
25
30
35
40
45
50
55
60
65
70
75
80
average score [%]
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Melatonin Correlation

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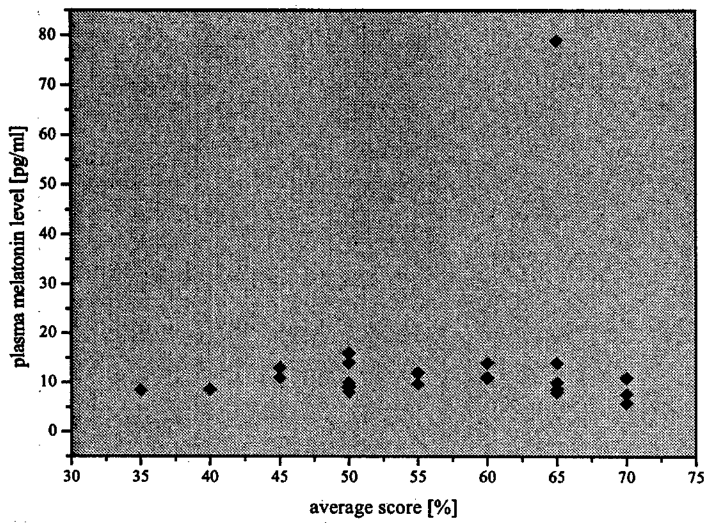

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Randomization

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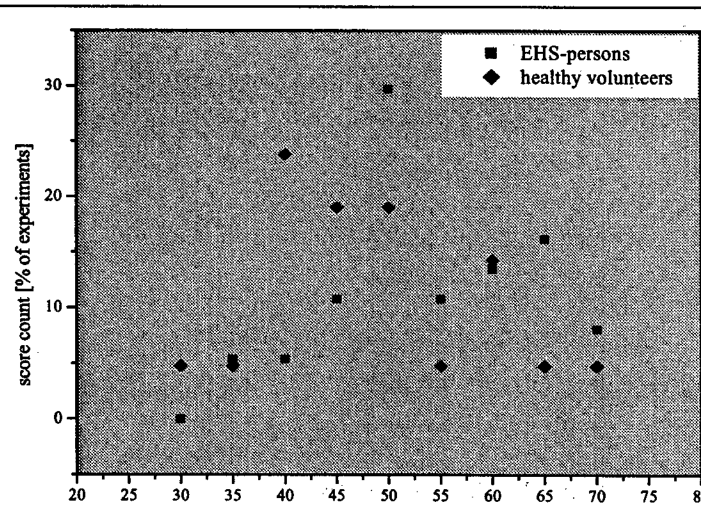

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Melatonin Time Course

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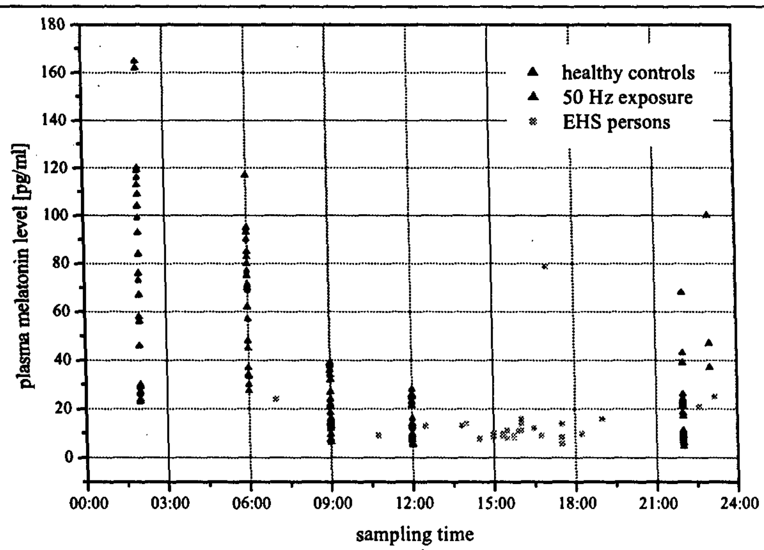

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Conclusion

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•Questionnaires:

»no symptomatic definition possible

»no hypochondria or hystery phenomenon

•Medical Check:

»no evidence for medical definition

•Exposure Experiments

»no increased perceptive abilities

➔ Future:

🡇 check stated exposures

🡇 combination of methods

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EMF-Related Activities in Thailand

Nisakorn Manatrakul

Not Available

MOVIE ON THE HEALTH EFFECTS OF THE CELLULAR PHONE & BASE STATION

Femme-Michele Wagenaar

Not Available

FMK SCIENCE HELP DESK

Sheila A. Johnston *

Not Available

International EMF Project

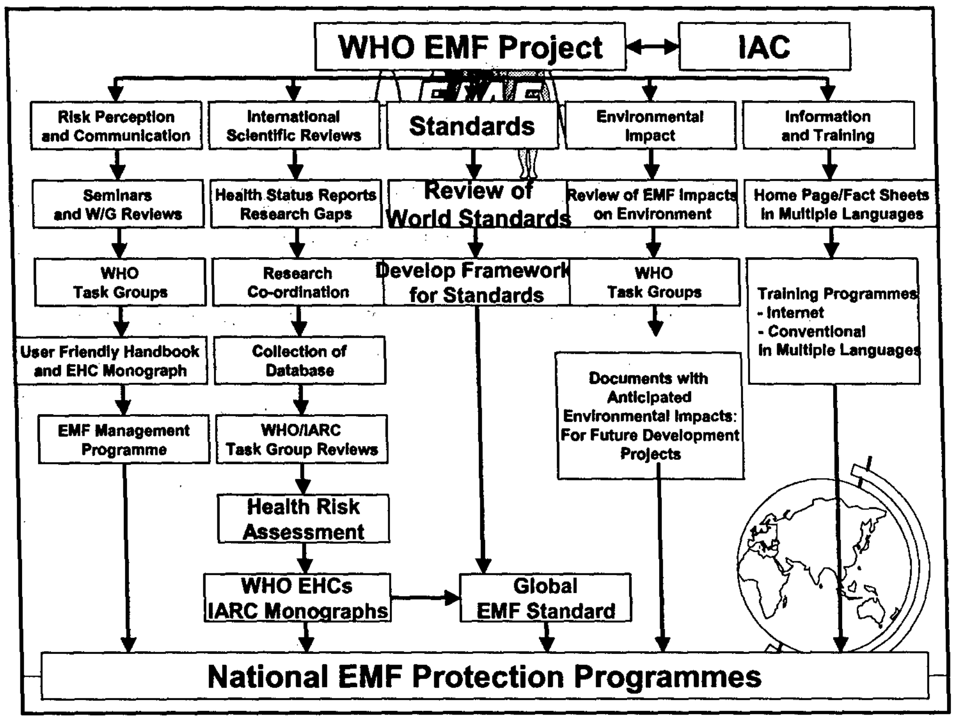
Standards Harmonization

WHO/ICNIRP/South Korean Government meeting EMF biological effects and standards harmonization in Asia and Oceania, 22-24 October 2001

Dr MH Repacholi
Co-ordinator, Occupational and Environmental Health
World Health Organization, Geneva, Switzerland

Collaboration

- International partners
  WHO, UNEP, ICNIRP, ILO, IEC
  IARC, NATO, ITU & EC
  - National partners >45
    - WHO collaborating institut
      USA, UK, Japan, Sweden &
      Germany
    - Independent scientific institutions



International EMF Project
Standards Harmonisation

Objective

Reach international agreement on a framework for developing guidelines on protection of the public and workers from exposure to EMF

International EMF Project

Standards Harmonisation

- Project facilitates international consensus on standards
- Project will identify health risks using WHO/IARC procedures
- WHO does NOT develop standards, only health risk assessments
- ICNIRP full partner in Project and develops international standard
- All major standards setting countries are involved in the EMF Project

EMF Standards Harmonisation

Benefits

- Increased public confidence that governments and scientists agree on health risks
- Reduced debate and fears about EMF -- precautionary principal?
- Everyone protected to the same high level

EMF Standards: Political Process

Protecting populations against potentially hazardous agents is part of the political process so there is no reason to expect that all jurisdictions will choose exactly the same levels of protection.

It is accepted and expected that different countries, and even different jurisdictions within a single country, may sometimes choose to provide different levels of protection against environmental hazards, responding to their citizens' wishes.

Disparities in National EMF Standards

Arisen in large part from:

- **different interpretations of the scientific data**
- **using different philosophies for standards development in the exposure limits and the scientific data used as a basis for standards**
- **differences in the way scientists interpret risk data and the nature of environmental risks**
- **possible deficiencies in communications among scientists between different regions**

STATUS OF STANDARDS HARMONIZATION

- Conducted scientific reviews, identified gaps in knowledge
- Currently promoting EMF research funding agencies to support WHO's research agenda
- Forming working groups to deal with key components of standards framework
- Will conduct formal health risk assessments that form the basis of an international standard
- Will encourage all EMF Project member countries to accept internationally agreed standard

All on home page at: http://www.who.int/emf/

Working Group on Standards

Topics for discussion

- Criteria for evaluating scientific studies
- Models for developing exposure limits
- Use of safety factors
- One or two tier standard?
- Form of the standard - indicate how to determine compliance?
- Scientific rational to support limits?
- Social and economic impacts...should they be considered?
- One standard cover for whole frequency range (0-300 GHz)?
- Other considerations?

Working Groups on Standards

- WG1: Standard concepts and terminology
- WG2: Criteria to evaluate research results. Scientific rationale to support limits, and comparison of various standards
- WG3: Model for developing standards. Safety factors: how should they address uncertainties
- WG4: Should social and economic impacts be considered? How should precautionary approaches be developed, if needed?

Workplan on Standards

- Working group meetings will be held, generally in conjunction with scientific meetings in key geographical regions that will allow the input of scientists and government officials in those regions
- Setting up working groups in each region will enhance the quality of communication among scientists and government officials, in examining the scientific basis for the standards and the assumptions that underlie them

Draft Schedule of Meetings

- Xi'an, China 23-26 October 2000.
- San Antonio, Texas 13-14 November 2000
- Lima, Peru 7-9 March 2001
- Bulgaria 30 April - 4 May 2001
- South Korea, 22-24 October 2001
- Cape Town, South Africa, 4-7 December 2001
- Working group, China 2002
- International meeting, Geneva 2004

Working Group on Standards

Want framework for standards completed by 2003-4 so it can be used to develop internationally agreed standards once the health risk assessment process has been completed 2005

Draft framework has now been developed and will be circulated during and after Regional meetings

WHO Meeting on EMF Biological Effects and Standards Harmonization in Asia and Oceania

22~24 October, 2001 Shilla Hotel, Seoul, Korea